Instruments

THE MAGAZINE OF

Measurement and Control

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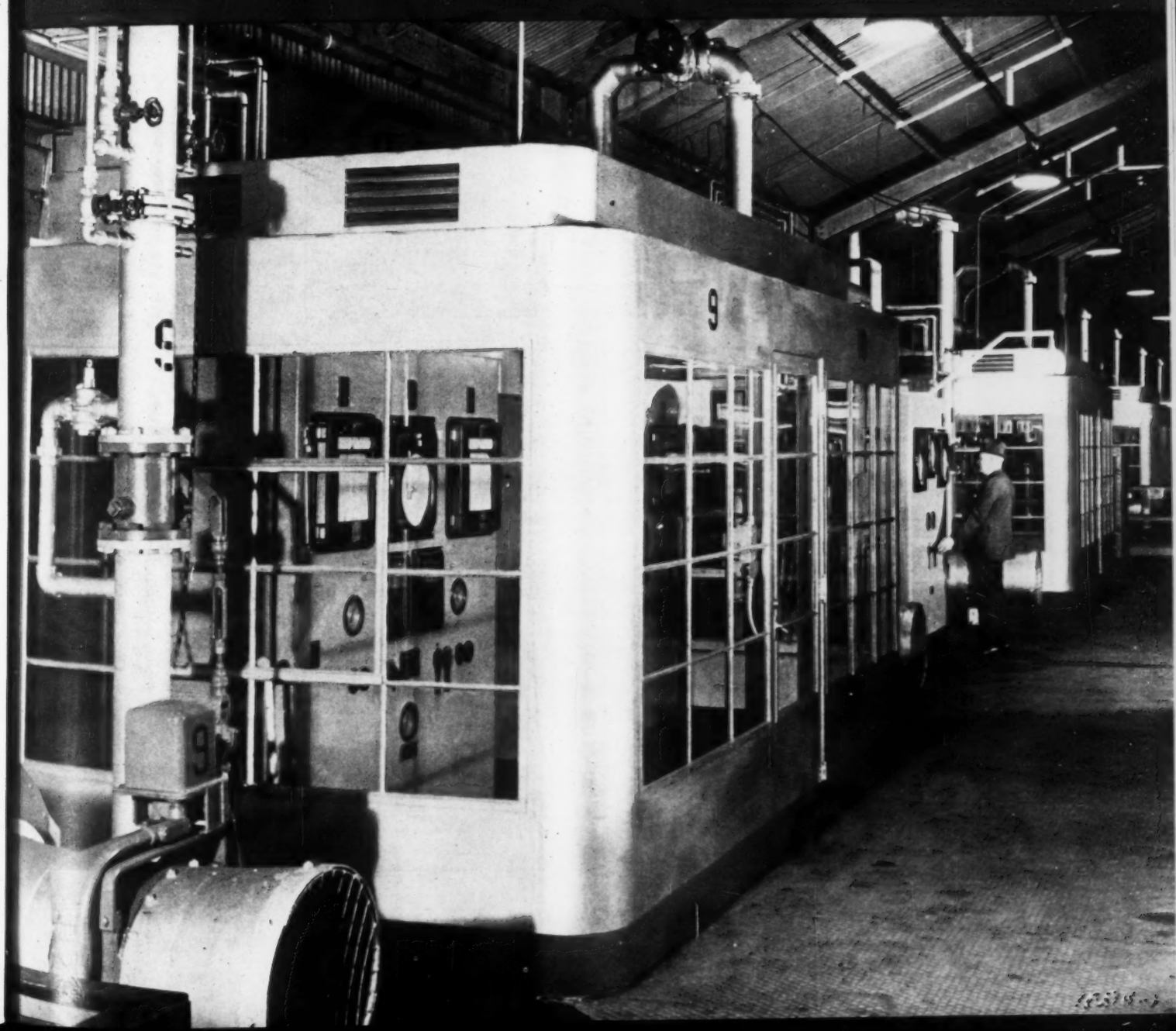
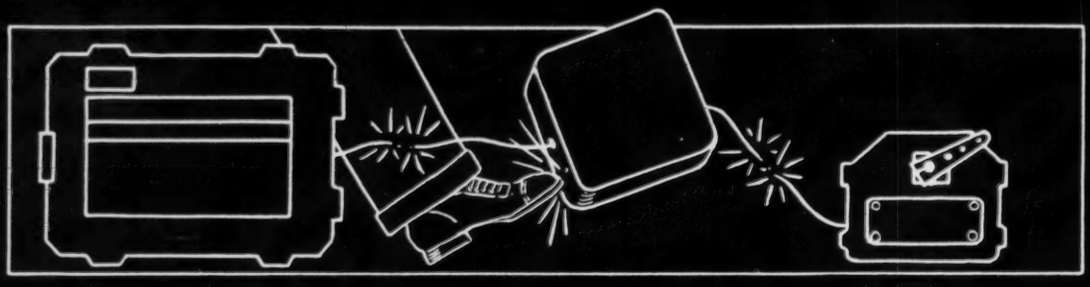
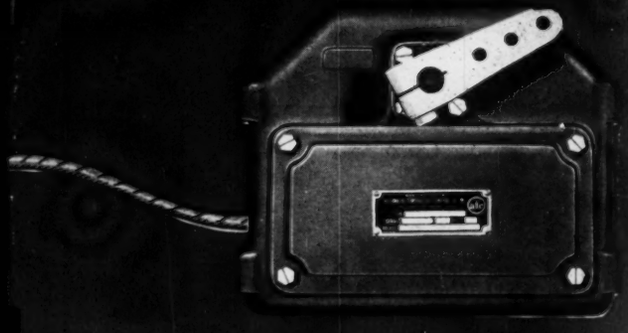
No. 5







What! no relay detector?

CELECTRAY THROTTLING CONTROL

A SIMPLIFIED METHOD OF PROPORTIONING FUEL HEAT!

The only equipment necessary, using the new TAG CELECTRAY method for throttling control of fuel heat, is the TAG Recorder Controller and a TAG Motor Operated Valve with slide wire arrangement. By eliminating the relay detector, the high precision CELECTRAY balancing is used for BOTH the recording carriage and the control valve . . . TWO UNITS instead of THREE offer obvious economies in original installations, as well as lowered maintenance expense. The practically "straight-line" control as recorded is a true indication of your actual furnace conditions because CELECTRAY has the smallest "dead zone".

All this adds up to better control and more uniform furnace atmospheres at rock bottom cost.

CELECTRAY throttling controller models with automatic reset, manual or no reset for your particular problems are also available. Learn now what these superbly simple, competent instruments can do for you in terms of product improvement, speeded production and lowered costs.

C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

Instruments THE MAGAZINE OF Measurement and Control

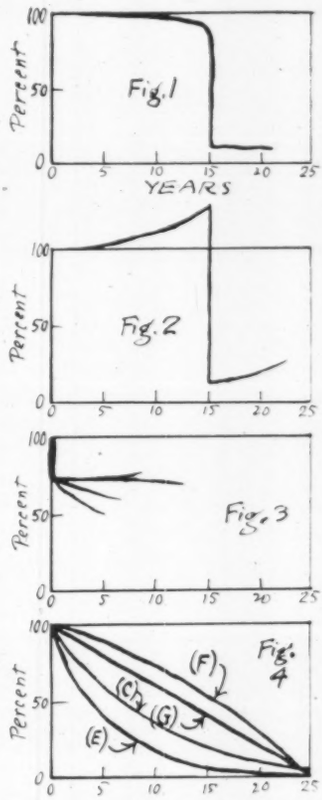
M. F. BEHAR, Editor

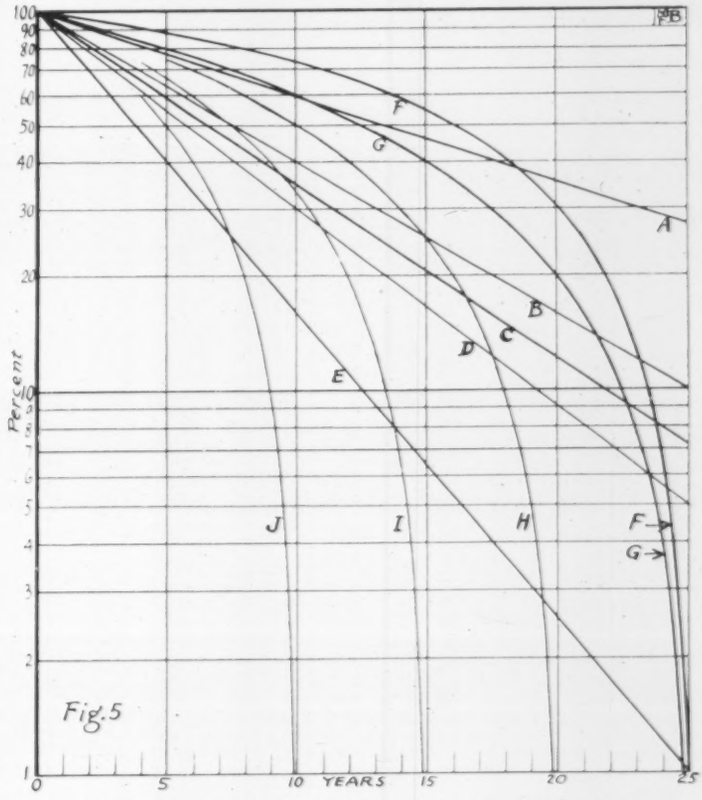
"Anticipatory Control" of Repairs or Replacements

All because a troop farrier hadn't taken business-school courses in Obsolescence Rates, Depreciation, Inadequacy, Supersession, Renewals and other financial subjects essential to keeping horses well shod in time of emergency.

WINNING the war on the production front against the mounting handicaps of scarcities calls for skill and ingenuity plus foresight and attention to details. You remember the old jingle about the successive losses of a horseshoe, of the horse, of the rider, of the battle, of the war and of the kingdom, "all for the want of a horseshoe nail!" Well, it seems that the famous last line should read:

I began learning about these mysteries in 1938 when, seeing that war was due to break out and cause a shortage of instruments, I planned for the publication of the service manual James Spencer was beginning to write and of other articles that would help *Instruments* readers solve these new problems. Humbly consulting corporation Treasurers and other experts, I gradually learned that a time of emergency is the very time when disaster may overtake an instrument department whose head, even if he is an ideal engineer, has not kept in close touch with his firm's financial executives.





Close touch implies ability to talk the same language when discussing provisions for the future. There are several languages, based on Price, Real Value, Book Value, Salvage Value, Scrap Value, etc. Even if engineers and accountants agree on the initial figures, they are likely to disagree on *rates* of change. One engineer may see no reason why an instrument's value shouldn't always correspond to its efficiency or condition until it fails beyond repair, when its value drops to scrap value, say 10% as in Fig. 1. Another may hold that in years of rising prices, such as 1930-1940, the book value rises and, even after failure, the value of the scrap rises likewise (Fig. 2). Another maintains that an instrument is like an automobile: the moment you take possession it becomes "second-hand" and you must write off about 25% (Fig. 3) before adopting any curve. Many engineers, having been trained in physics, prefer the logarithmic-decay curve where the value at time t in terms of the initial value (V_{100}) is given by the familiar equation $V_t = V_{100}e^{-kt}$ in which k is the decay coefficient and its reciprocal, times various well-known factors, gives various moduli. Thus, for 1% salvage value at 25 years, $k = \log_e [(100/1)]/25 = 0.2760$. Or, for a 10% rate (see curves C, also Paul MacGahan's article on page 173) $k = 0.10526$.

Most financial executives recommend the so-called straight-line method (curves G, H, I and J) because the Federal income-tax people accept it; but they will tell you that various types of plants come under various Federal and State regulatory bodies which, collaborating with various industry institutes and stockholders' associations, have worked out various scientific curves. Examples: curve E is the reducing-balance method and curve F the sinking-fund method. As a rule they start from an exact final value or salvage value and apply compound-interest principles, which we engineers know as geometrical progression and to use which we simply draw straight lines on semi-log paper (examples, B for 10% and D for 5% scrap values at 25 years). When graphs are not sufficiently precise, the exact value of the "compound interest" is

$$100\{[(V_{100}/V_s)^{-N}]-1\}$$

where V_{100} is the cost value, V_s the salvage value and N the number of years. Thus for curve B the interest is 9.65% and the annual decay is 8.80%. Conversely, for the 5% annual decay curve A, the interest is 5.26%. —MFB

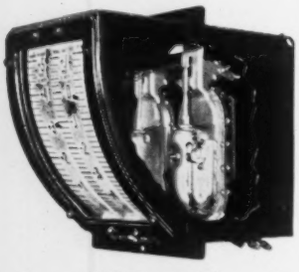
BAILEY METERS

METERS and CONTROL
for Boiler Room Service . . .

Boiler Meters Reduce fuel costs, lessen maintenance and outage, lower standby costs, and add capacity. They indicate, record and integrate Steam Flow from the boiler, record Air Flow supplied for combustion and record Flue Gas Temperature.

Bailey Boiler Meter

Multi-Pointer Gages for indicating drafts, pressures, differentials are available with any number of pointers from one to twelve. They are actuated by sturdy yet sensitive diaphragm units.



Multi-Pointer Gage

Flow Meters. For indicating, recording and integrating the flow of steam, feed water, compressed air and other fluids.

Coal Meter

Granular Material Meters For accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems Make possible the everyday operation of equipment for steam generation and utilization at test efficiencies. They are applied to the control of combustion, feed water, superheat, desuperheat and other factors.

Complete Information on any of the above Bailey products will be gladly furnished upon request.

G-14

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

BAILEY METER COMPANY LTD., MONTREAL

THE MONTH'S NEW INSTRUMENTS

In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control.

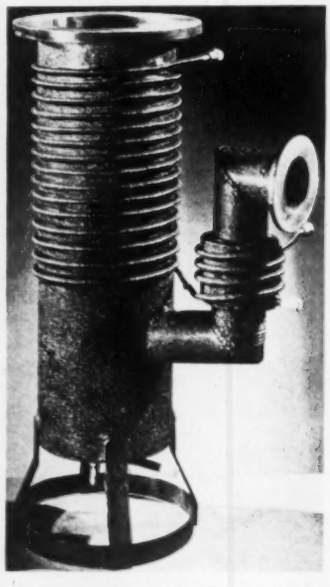
When writing to manufacturers directly, please mention this department as your source of information. Or write to Information Section, Instruments Publishing Company.

Decade Capacitor

A choice of any capacity value from 0.01 to 11.1 mfd. in 0.01-mfd. steps, or other ranges, at the twist of three knobs, is provided by new "Decade Capacitor Type DK." The 1% accuracy of the instrument is said to make it suitable for most laboratory as well as industrial applications, particularly for bridge measurements, filter design, and experimental tuned circuits. Instrument is housed in walnut cabinet with hinged cover and snap lock. Etched metal panel has three knobs and dials calibrated directly in capacitance so that reading from left to right totals up the value available at the binding posts. Adjustments are made progressively in small uniform steps. Dimensions, 7" × 8" × 5¾"; weight, 8 lbs. Three models are available: 11.1 total in .01 mfd. steps; 1.11 mfd. in .001 steps; and 1.11 in .001 steps with mica dielectric throughout.—*Industrial Instruments, Inc., 156 Culver Ave., Jersey City, N. J.*

Metal Booster Pump for Vacuum Applications

Designed for use with forepumps having low volumetric efficiency at pressures below 1 mm. of Hg, a new high-capacity metal vacuum pump, known as the "Metal



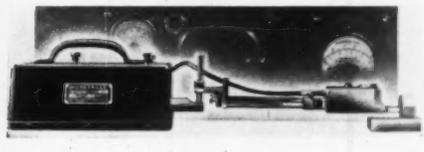
Booster Pump, Type MB-200," is a 2-stage oil diffusion unit which will boost the pumping speed to 200 l./s. and will carry the vacuum from 0.5 mm. to 5×10^{-5} mm. of Hg. Unit is small and compact, having a vertical casing 6" by 20", and is readily connected to large mechanical pumps by 1½" standard pipe fittings or in the optional model illustrated by a 2" i.d., 4" o.d. flange. The vacuum attainable is sufficient for metal sputtering and evaporation, ultracentrifuges, vacuum insulated flasks, and drying chambers.—*Distillation Products, Inc., Rochester, N. Y.*

Multi-Range Tester

New "Series EV-10" is a vacuum-tube type tester described as "a compact, yet complete, ultra-sensitive, multi-range test set" and said to provide "the full functions of eight individual instruments to satisfy most all measurement requirements of the present and future electronics, communications and electrical fields." Incorporating a voltage-regulated bridge type circuit, it provides the following ranges on an 8½" indicator: Eight zero-center V.T.V.M. ranges, from ±3 to ±6000 volts d.c.; six circuit-probing zero-center v-t.v-m. ranges from ±3 to ±600 volts d.c.; six ohmmeter-megohmmeter ranges up to 2000 megohms; eight a-c. and eight d-c. voltage ranges at 1000 ohms per volt from 0-3 to 0-6000 volts; seven d-c. current ranges, 0-600 ma. to 0-12 amps.; eight a-c. output ranges to 6000 volts; eight decibel ranges from −26 to + 70. Available as an accessory is an RF-10 vacuum-tube probe which provides direct means for measurement of supersonic, rf. and uhf. voltages.—*Precision Apparatus Co., 647 Kent Ave., Brooklyn, N. Y.*

Automatized Surface-finish Tracer

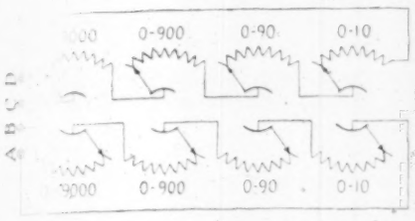
Newly-designed "Type V Mototrace," an accessory used with maker's "Profilometer" for mechanical tracing of surface finish, has a number of new features not found



in "Type U" which was formerly manufactured. Original unit was mechanically operated by a cam and toggle acting on a rack. This method has been replaced by the use of a 9-watt driving motor which itself is reversed. With this design, a length of stroke from ⅛" to 2¾" can be obtained. Beside a long available trace, the former "dead spot" from ⅛" to ⅝" is eliminated, thereby allowing continuously adjustable setting. Provisions have been made so that, if motor should become locked, it does not heat up and motor is not damaged. New Mototrace, shown in use with the "Type I" (internal) Tracer and Profilometer, also has fewer controls than previous model. All operations are now controlled by the power switch and two adjustable stops. This new Profilometer accessory is said to be especially valuable for securing "accurate readings on very fine surfaces." By its use, Profilometer tracer is drawn without vibration across piece being measured. It is useful also for measuring softer materials, awkward shapes, distances as short as ⅛" and surfaces such as those in small holes, adjacent to shoulders or bosses, and on gear and hob teeth.—*Physicists Research Co., 343 South Main St., Ann Arbor, Mich.*

cade Voltage Dividers

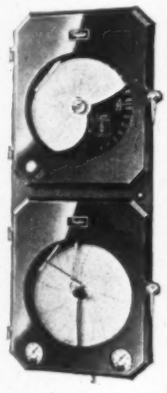
s voltage diivders can now be fur- n decade form and any capacity libration desired, for experimental, and routine work. Due to maker's design of rotary instrument

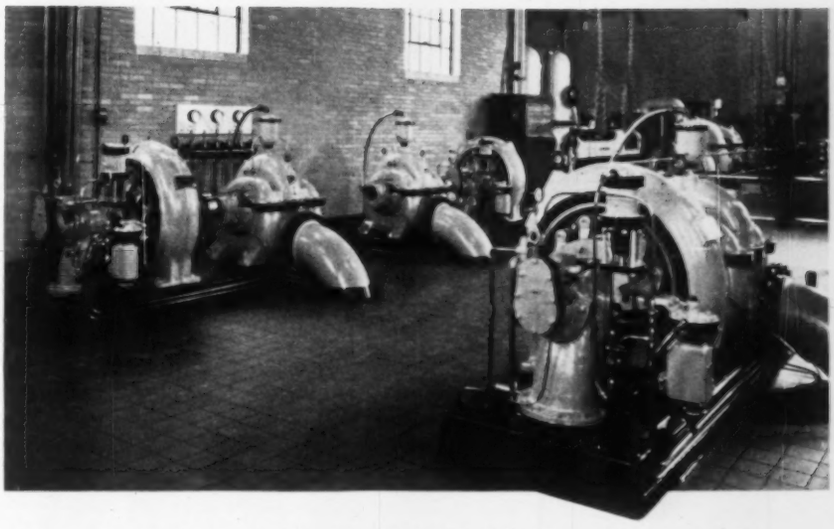


switches and decade resistance boxes, the following flexible arrangement is possible and practicable: any desired series of decade voltage dividers is readily arranged —and always with a constant internal resistance. Diagram shows a typical 10,000-ohm set-up having four dials. Resistance *AB* and *CD* may be used independently (as a resistance box). When dials are rotated clockwise, resistance *AB* will be increased and resistance *CD* will be decreased. When used as a voltage divider, a link (provided with the set) is placed across *B* and *C*. This makes the resistance *AD* constant at all settings of the dials. If a voltage *E* is impressed on *AD*, voltage *e* across *AB* will be $e = pE$, where *p* is the voltage ratio indicated by the dial settings. Voltage ratios of 0.0001 to 1.0, as well as other ranges, are available.—*Shallcross Mfg. Co., Collingsdale*, Pa.

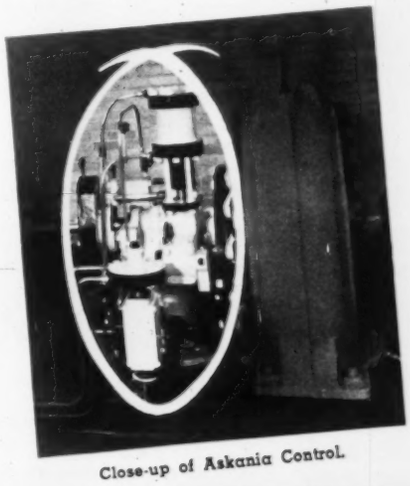
Time Schedule Controller

Controlling temperature, pressure, flow or liquid level according to a predetermined time schedule is duty of new "Taylor Fulscope Time Schedule Controller." After a desired process schedule has once been determined, this new instrument makes it possible to carry it out automatically. As may be seen, the cam and the chart are individually mounted and conveniently located for instant visual comparison. Among improved features are: friction drive cam assembly which permits rotation of cam without loosening any locking means; improved means of resetting one cam without disturbing the other in an instrument with two complete control mechanisms; each cam capable of operating from one to four air valves, micro-switches or both for commanding a valve, bell or light, and do this automatically in any desired relation of one to the other; and the automatic return of the cam to the starting position. An optional feature is the Interrupter Timer which allows extreme flexibility to both the rise and the holding periods of the process under control. This timing feature allows the use of a fast cam clock for a rapid rising period, but reduces the speed of the clock to increase the length of the holding period. The rising period, the holding period or both may be increased as much as 6½ times normal period, obviating the need for a separate timing controller. New time schedule controller incorporates maker's "Fulscope" control system and is available in all control forms, including automatic reset and "Pre-Act." By the addition of pre-calibrated assemblies it can easily be converted to fit any process requirements which might arise in the future. Universal case for face or flush mounting. —*Taylor Instrument Companies, 95 Ames St., Rochester, N. Y.*





It takes ASKANIA to solve a control problem like this—



Close-up of Askania Control.

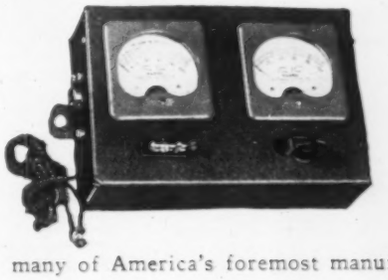
THE problem here at this large Mid-western Water Distribution Plant was to accurately maintain the level in a water reservoir by changing the speed of water driven turbines.

It was solved by the Askania System in which an Askania Jet Pipe Regulator automatically controls the wickets of the water turbines from an impulse produced by the water level of the reservoir.

This is just one more example of the unmatched versatility of the simple, stable, positive Askania Jet Pipe Principle. Perhaps it will suggest the solution to your automatic control problem.

ASKANIA REGULATOR CO.
1605 S. Michigan Ave., Chicago, Ill.

ASKANIA
REGULATOR CO. CHICAGO
AUTOMATIC CONTROL



TRU-VAC
VACUUM GAUGES
(PIRANI TYPE)

Shown at left is meter box of our model No. 6 gauge.

This gauge successfully used by many of America's foremost manufacturers.

Send for circular on our new low priced D.C. operated gauge.

CONTINENTAL ELECTRIC CO.
GENEVA, ILLINOIS

Low-frequency LINEAR-TIME-BASE Generator

★Still another outstanding contribution to cathode-ray oscillography—the new DuMont Type 215 Low-Frequency Linear-Time-Base Generator. This accessory instrument used in conjunction with a DuMont Type 175A or equivalent cathode-ray oscillograph, permits studies requiring sweep frequencies as low as one cycle every few seconds. Note this check list of main features:

- Sweep frequency range of 0.2 to 125 cycles per second.
- Balanced output signal voltage.
- Undistorted output signal of approximately 450 volts peak-to-peak.
- Single sweep initiated either manually or by observed signal.
- Excellent linearity assured by compensating circuit.
- When used with DuMont 175-A Oscillograph, pattern may in effect be spread out to an extent corresponding to approximately three times full scale deflection, or 15".
- Operates on 115 or 230 v., 40-60 cycle a.c. 50-watt consumption. Portable steel case with carrying handle. Etched black panel. 14½ h., 8 13/16" w., 19¼" d., 41 lbs.

★ *Write for Literature . . .*

DUMONT

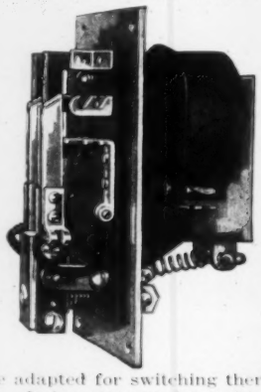
ALLEN B. DU MONT LABORATORIES, Inc.

Passaic ★ New Jersey

Cable Address: Wespexlin, New York

Vibration-proof Relay for Milliamps at Microvolts

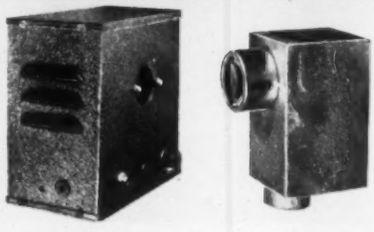
Designed to handle circiuts carrying milliamperes at microvolts in radio applications, new "Dunco CX3318" laminated frame relay has sliding contacts and is



likewise adapted for switching thermocouple circuits. It is constructed to withstand extreme vibration incident to aviation service and, like maker's other units for this field, is tested for operation at high altitudes. New relay is 3⅜" high × 2" wide and 2¼" deep and weighs 9½ ounces. Contacts are double-pole double throw. Coils are for operation on a.c. only, and are shielded from the contacts. — *Struthers Dunn, Inc., 1315 Cherry St., Philadelphia, Penna.*

Anti-sabotage and Blackout Photoelectric Systems

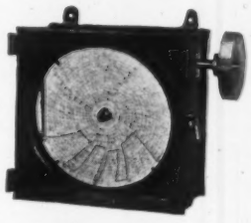
Utilizing time-tested operating principles and components, but designed for specific war-time applications, several new units, assemblies and systems are announced for plant protection, automatic blackout, etc.



(1) *Anti-sabotage Equipments.* — Giving visible or audible alarm or both in case of trespass, and locating and exposing the trespasser, units are available for outdoor service (illustrated) or indoor installation. Units are small and easily camouflaged. Outdoor systems locate trespasser within 500 feet; indoor systems show room in which trespass is made. Alarm can be given without warning trespasser audibly or visibly. Optionally, where it is desirable to put the criminal "on the spot," a surprise floodlighting system is automatically turned on, for which purpose an obsolete continuous-floodlighting system can be converted.

(2) *"Blackout Warden."* — Lower part of illustration shows one of the new equipments for automatically turning off electric signs, store windows, etc., during a blackout and automatically turning them on again. Two models: "No. 3001" is a single-unit model with amplifier, relays, sensi-

Amthor



Operation Speed Recorder

8" Chart
12 or 24 hr.

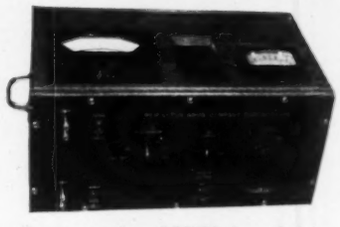
Built for severe service. Users report 10, 12 or more years of trouble-free life. Powerful centrifugal speed-measuring element stays calibrated. Non-spill reservoir pen. Special chart paper. Rugged clock movement. Ideal for analysis of new War Effort jobs.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems. Drop us a line today.

Amthor Testing Instrument Co., Inc.

49a Van Sinderen Ave. Brooklyn, N. Y.

REMINGTON ARMS CO. CHRONOSCOPE



Accurate Within 1% Between 1 & 200 Milliseconds

Inquiries Invited

Dynamometers, wattmeters, milliammeters and voltmeters. Also ultrasensitive meters both for A.C. & D.C., fluxmeters, electrostatic voltmeters from full scale 120 volts to over 20,000 volts, thermocouples, earth current meters, cable testers, etc.

Special Apparatus Built to Order

RAWSON ELECTRICAL INSTRUMENT COMPANY

110 Potter St. Cambridge, Mass.

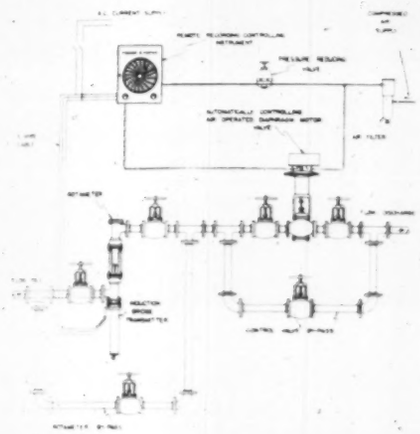
Branch: 15 East 26th St., New York City

Representative: E. N. Webber
4358 W. Roosevelt Rd., Chicago, Ill.

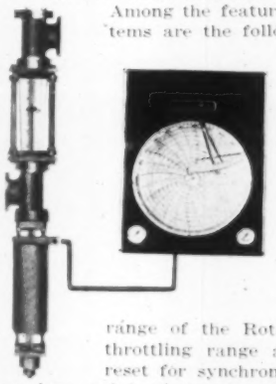
...egulators and photoelectric cell, all ...housing. "No. 3002" consists of ...p... unit and "electric eye" unit; is the ...s 3001 in all other respects. "Elec... unit is weatherproof so it can be ... sufficiently close to the street light, ...is the controlling light source for all ...out Wardens." Coaxial cable is used ...nect the "electric eye" unit to the ...ing unit.—*Warner Products Corp., W. Lake St., Chicago, Ill.*

Flow-rate Recorder-controller

A series of new combination transmitting ...meters, control instruments, control ...ves, etc., is announced for automatic ...ntrol and permanent chart record of

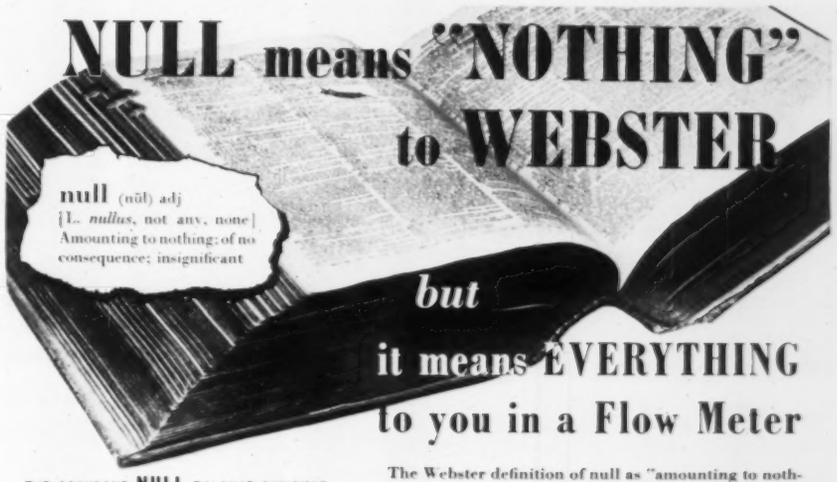


liquid or gas flow rates. Systems are especially valuable for measuring and controlling flows of viscous and corrosive fluids, such as fuel oils, sulphuric acid, caustic, hot tar and organic liquids, which no other controller can successfully handle.



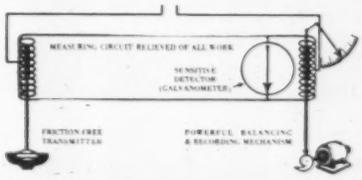
Among the features of new systems are the following: All the advantages of the standard Rotameter flow rate instrument plus completely automatic flow control; control point adjustable to any point over the entire flow range of the Rotameter; 150% throttling range and automatic reset for synchronizing to process lags and load changes; flow controlled directly from remote panel-mounted instrument; permanent record of flow provided; indication of flow-rate at Rotameter itself in case of power failure. Rotameter float position is transmitted to the recorder pen arm through the use of a self-balancing induction bridge. When the recorder pen arm is not at the same position as the control index arm, a flapper changes the air pressure within a bellows type control system. Changed air pressure opens or closes a diaphragm motor control valve in flow line to bring rate of flow back to the desired control point and to keep it at that point. Meter is made with indicating-controlling, recording-controlling, or recording-integrating-controlling features to suit any specific requirements. The "Rota-Matic" can also be used to control the quantity of one flow in constant ratio to the amount of another flow. In addition, time cycle variations of control point are possible.—*Fischer & Porter Co., Hatboro, Pa.*

NULL means "NOTHING" to WEBSTER



but it means EVERYTHING to you in a Flow Meter

THE COCHRANE NULL BALANCE PRINCIPLE


MEASURING CIRCUIT RELIEVED OF ALL WORK
SENSITIVE DETECTOR (GALVANOMETER)
FRICTION-FREE TRANSMITTER
POWERFUL BALANCING & RECORDING MECHANISM

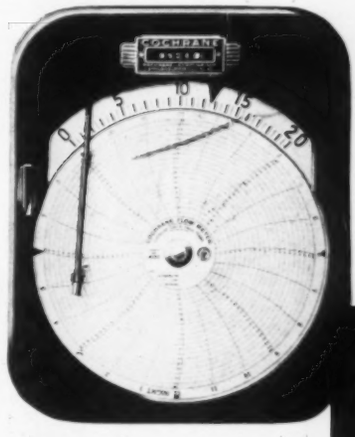
The Webster definition of null as "amounting to nothing" is the significant point in specifying a Cochrane Flow Meter, for Cochrane design is based on the NULL balance principle, long recognized as the most accurate means of measuring a force or quantity.

It means "zero" error in the measurement of flows, temperatures, liquid levels, pH values, etc.

The null or zero balance principle consists of balancing the unknown quantity by adjusting a known quantity of the same kind, a highly sensitive indicator being used to determine the point of balance.

It is the method used in the Cochrane Electric Flow Meter, distinguishing this meter from all others.

Note: a bridge circuit alone is *not* a null method meter. A galvanometer is required to detect unbalance and an external source of power is needed to restore balance. These are found ONLY in the Cochrane Electric Flow Meter.



COCHRANE CORPORATION
3120 N. 17th STREET PHILADELPHIA, PA.

Cochrane FLOW METERS

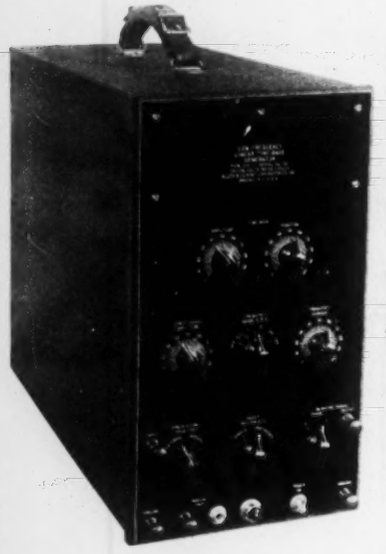
There's a SUPERIOR LITTELFUSE AND MOUNTING FOR EVERYTHING IN THE BOOK!

"Quicker than a short circuit" LITTELFUSE meets your most exacting requirements. If yours is production of the highest quality, *it deserves LITTELFUSES, the most advanced science in construction* for mechanical strength, vibration life, fatigue, resistance, dependability. Let us show you how to cut costs by fusing with Instrument Littelfuses. Other Littelfuses for auto, radio, high voltage, meters, aircraft, Neon testers and indicators. Send for complete Catalog.

LITTELFUSE INC. 4759 RAVENSWOOD AVE CHICAGO, ILL.

Low-frequency Linear-time-base Generator

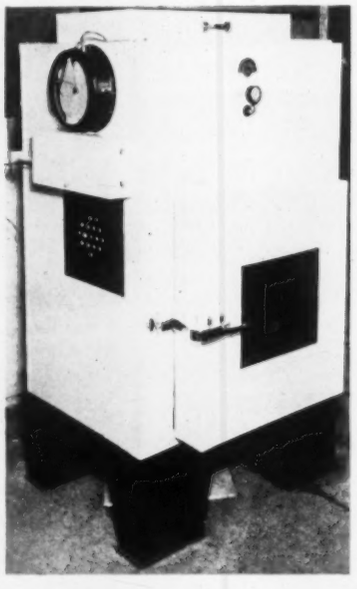
For those oscillographic studies requiring sweep frequencies as low as one cycle every few seconds, new "Type 215 Low-frequency Linear-time-base Generator" is for use in



conjunction with an oscillograph provided with a long-persistence cathode-ray tube, or with photographic recording methods. Vibration studies, stress and strain measurements, low-frequency electrical observation, electrocardiography and electroencephalography, are facilitated by this new unit. Frequency range corresponds to rotating speeds of 12 to 7500 r.p.m., thus permitting the use of an oscillograph for the visual study of certain characteristics of rotating machinery at low and medium speeds. Transient observation is provided for by a single-stroke sweep circuit. New generator provides a sweep frequency range of 0.2 to 125 cycles per second. Maximum undistorted output signal is approximately 450 volts peak-to-peak, balanced to ground. The single sweep is initiated either manually or by observed signal. "Excellent linearity is assured by a compensating circuit." Thoroughly portable, instrument measures $14\frac{1}{4}$" h., $8\frac{15}{16}$" w., $19\frac{1}{2}$" d., and weighs 41 lbs. Steel cabinet, black wrinkle finish, with carrying handle. Etched metal black panel. 115 or 230 volt r.m.s. 40-60 cycle. Power consumption, 50 watts. 1 amp. fuse protection. The primary voltage is selected by a switch in the instrument. — *Allen B. DuMont Labs., Inc., 2 Main Ave., Passaic, N. J.*

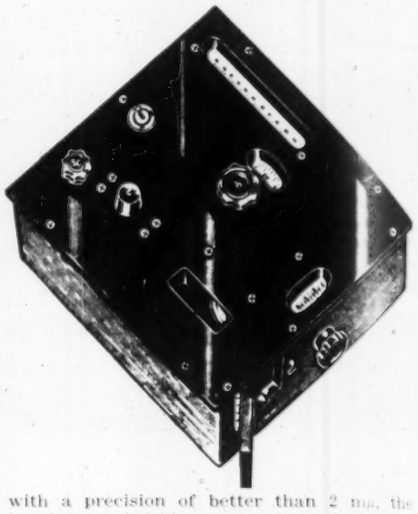
"Stratosphere Chambers"

Announcement is made of a series of enclosures for testing aircraft instruments and other equipment under conditions simulating actual flights from ground level to high altitudes. Temperature, pressure, humidity and ventilation are all controlled in the standard cabinets; other chambers are available in which any one, two or three of these four factors (as selected) are controlled. Illustration shows one model of a "stratosphere chamber" in which all four factors are controlled; but manufacturer informs *Instruments* as this issue goes to press that it is not the definitive model: modifications are optional and most recent (May 1942) refinements are not shown in this photograph. In general, however, "stratosphere chambers" employ the dry-ice method of producing low temperatures and a specially-designed water spray unit operating in conjunction with an automatically-controlled water heater to produce and maintain the desired humidities. —*Tenney Engineering, Inc., 15 Ward St., Bloomfield, N. J.*



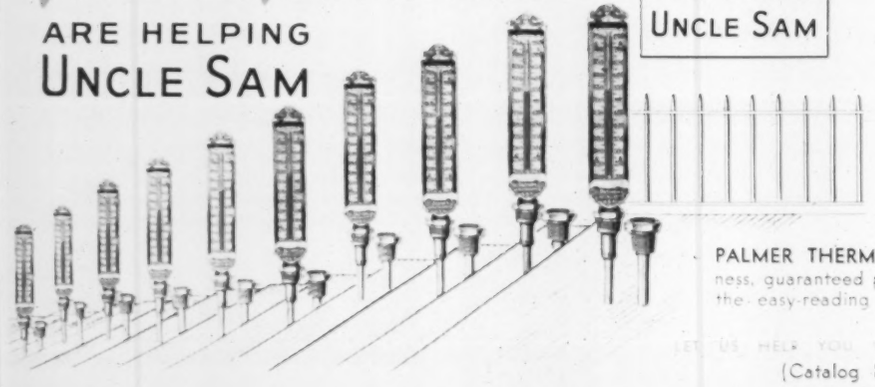
Universal Spectrophoto[meter]

New "No. 11 Coleman Universal [spectro]photometer" is said to meet the mu[ltiplicity] of demands occurring in the modern [labor]atory where light is used as an [optical] tool. Instrument allows selecting a [monochro]matic band of lightmμ wide an[d] within the spectral region of 300- [mμ] and since this band width can be [regulated]



with a precision of better than 2 mμ, the instrument, in this respect, is equivalent to a high-grade colorimeter equipped with an infinite number of high-quality filters. When fitted with "UV Illuminator U-11-M," instrument is further a daptable to quantitative determinations of Vitamins B_1 and B_2 and other fluorescent materials. It accepts cuvettes exhibiting film depths from 0.1 to 50 mm. Instrument was developed in conjunction with Dr. R. W. Wood of Johns-Hopkins University, and contains one of the special echelette gratings which he has developed. It will pass color bands of light of any desired hue or shade through liquid samples, even extending to those invisible light bands at either end of the visible spectrum. Absorption by samples forms a definite, accurate measure of the color characteristics. Extreme variety of "colored" light is available instantly by merely turning a dial. A control chemist can record exact characteristics of any industrial product which can be made to transmit light; can make exact color reproduction or control uniformity of oils and fats, dyes, pharmaceuticals, liquors and plastics. —*Coleman Electric Co., 310 Madison St., Maywood, Ill.*

Palmer Thermometers
ARE HELPING
UNCLE SAM



HELP WANTED
UNCLE SAM

Did you know that it requires over 200 Separable-Socket style Thermometers to properly operate ONE U.S. Battleship?

The demand placed on the Thermometer Industry for these requirements alone is heavy but to win this war, we must all co-operate.

To work for Uncle Sam, the thermometers must be strong, they must register quickly and accurately and they must be easy-to-read.

PALMER THERMOMETERS are known for their sturdiness, guaranteed permanent accuracy, their sensitivity and the easy-reading Red Reading Meniscus feature.

LET US HELP YOU WITH YOUR THERMOMETER PROBLEMS

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THE PALMER CO., Mfrs.

2511 NORWOOD AVE., CINCINNATI, NORWOOD, OHIO
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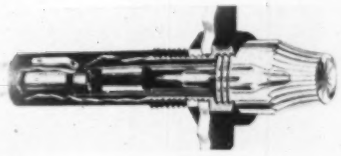
uit-break Warning Light

"Littlefuse Panel Mounting, No. has for its purpose to flash a light hen the circuit is broken. Originally, ndicator was designed for use in



lway signaling equipment and aircraft pplications, but it is equally applicable to ny circuits, circuit breakers, line switches, etc. Installed at any convenient point in connection with remote control it works instantly to show "on" or "off." When the circuit breaker opens the light goes on. It can be had for 24- or 48-volt filament bulb, with which no resistor is used. Otherwise it uses a built-in 200,000-ohm protective resistor, in series with a neon lamp. Resistor prevents lamp from blowing out, as ordinary lamps do, on unexpected high voltages. Lamp glows on currents as low as 100 microamperes. Indicator has a black Bakelite body and transparent molded cap. It is made for panels up to 5/16" thick and 1/2" diameter mounting hole. Overall length 2" below panel, 7/8" above panel. Rating is 90 to 250 volts. Regularly furnished without lamp.—*Littlefuse Incorporated, 4757 Ravenswood Ave., Chicago Ill.*

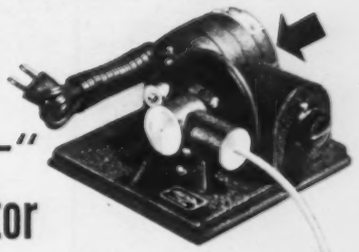
"Cold Treater"

New industrial type sub-zero "Cold Treater" refrigerators maintaining temperatures down to −35°F. have been announced for laboratory research and testing, and

production processing, aging, manufacturing and assembly. These refrigerators used in airplane, chemical, rubber, machinery, instrument and other industries, are built in 3 and 6 cu. ft. capacities. Large single lid gives complete access to interior. They are equipped with self-contained, trouble-free sealed condensing unit ready to plug in and use. Standard control maintains temperatures from +5° down to −10°F. Special control gives temperatures from +20° to −35°F. Cabinets are available with any specialized types of containers, racks or shelves.—*Jewett Refrigerator Co., Inc., 26 Letchworth St., Buffalo, N. Y.*

"Accurate, Quiet-Running, Durable—"

Electric Instrument Motor



Dental instruments, like any other kind, must be of top quality in order that they will last and give continuously satisfactory service. The electric motor which drives it is an important part of any instrument. That's why Bodine fractional horsepower motors are so widely used in instruments of all types.

A Bodine motor was chosen for the instrument above because of "the cooperation of the Bodine engineering department in selecting the type of motor best adapted for the purpose" and because of its accuracy, its quiet operation, and its durability. These factors are important to every instrument manufacturer. Bodine Electric Company, 2254 West Ohio Street, Chicago.

Clev-Dent Pneumatic Condenser

A Dental Instrument

Built by The Cleveland Dental Manufacturing Company, Cleveland, Ohio, this instrument condenses gold foil and amalgam fillings in teeth. It takes the place of hand or mallet pressure and produces a denser filling. Its manufacturers chose a Bodine motor to "provide dependable power."

BODINE

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A NEW ELECTRIC BOND TESTER

MILLI-OHM-METER MODEL

Ranges 0.5: 0.1: 0.05: 0.01: 0.005: and 0.001 ohms, at full scale

DOES NOT REQUIRE REFERENCE CURVES OR CHARTS . . . THE MEASURED RESISTANCE IS DIRECTLY READ FROM METER SCALE.

The battery-meter and controls are in the case . . . fixed clamp and exploring cables are easily connected.

Send for your copy of Bulletin No. B-16, details and prices are given. These low-resistance testers can be used by non-technical personnel.

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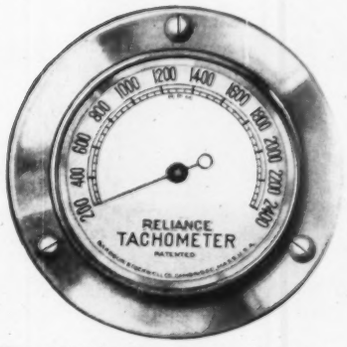
THE DAVEN COMPANY
158 SUMMIT STREET • NEWARK, N. J

Comparator for Toolroom or Production Line

New "Amic Comparator" employs a unique interior mechanism (pat. app. for) wherein two parallel flat springs mounted to two parallel vertical surfaces actuate a

horizontal yoke shaped like a letter V laid on its side. A spring-band stretched between the two ends actuates in turn the jewel-mounted main spindle which carries the indicating hand. A magnification of 1000× is thereby obtained without backlash and with negligible friction. Main Spindle carries an aluminum damping vane in the field of a permanent magnet, so that indicating hand comes to rest in minimal time without overshooting. Dial scale is 6" long, with 0.1" divisions representing ten-thousandths; also Metric graduations. Adjustable red sliders indicate high and low limits for production-line gaging (see illustration). Standard instrument can measure 6" maximum height; higher columns can be supplied. Working circle by swiveling, 10" dia. Base dimensions, 9⅝"×8". Weight, 38 lbs.—*American Measuring Instruments Corp., 50 West 22nd St., New York City.*



RELIANCE TACHOMETERS

FOR over 25 years the Reliance Tachometer has proved outstanding in Efficiency, Accuracy and Dependability for measuring speed of production on industrial machines in standard units:—yards per minute, feet per second, Newspapers per hour, etc.

Various Standard types of Reliance Tachometers are usually available for the above purposes, or special instruments may be obtained, on order, to meet specific requirements.

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MERCURY TO MERCURY BREAK
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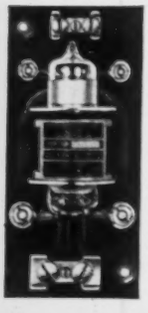
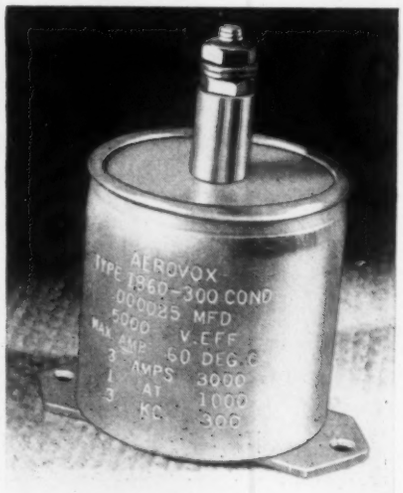


This accurate unit has been tested to 10 million operations without a failure. Available up to 30 amps. or one horse power rating. It will operate within 45 degrees of vertical. Bulletin B gives full details; write for it today.

H-B ELECTRIC CO., INC.
Manufacturers of H B Electrical Devices
2519 NO. BROAD ST., PHILADELPHIA, PA.

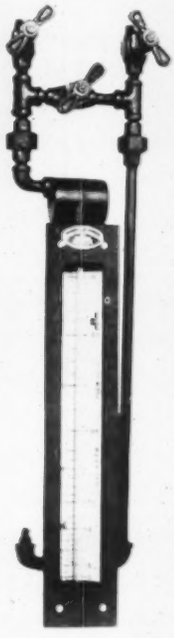
U-h-f. Aluminum-case Transmitting Capacitors

For use in ultra-high-frequency transmitters, as well as in miscellaneous applications in the u-h-f. range, new "Type 1860" transmitting capacitor is readily



adaptable for use as a fixed tuning capacitor, for by-passing, blocking, coupling and neutralizing, and as an antenna series capacitor. Losses are said to be extremely low. Aluminum case is 2" dia. by 2" or 2½" high; mounting base has two holes for 10-32 screws. Units are available in 0.00001 and 0.000025 mfd. in 10,000 volts; and 0.00005 mfd. in 5,000 volts.—*Aerovox Corp., New Bedford, Mass.*

TRIMOUNT INDICATING FLOW METERS



BUILT in open and fully enclosed models for indicating the flow of liquids and gases. For measuring hot or corrosive liquids, or steam, Trimount seal pots are available to seal the liquids from the gauge. Complete with mercury return trap to prevent mercury from entering line, nest of equalizing valves, mercury fill plug and thumb screw zero adjustment. Pressures to 125 lbs.

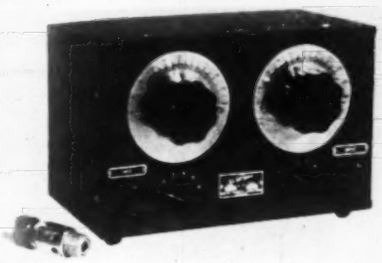
WRITE FOR NEW CATALOG

Describes Trimount Flow Indicators, complete line of Manometers and Tank Liquid Level Gauges.

TRIMOUNT INSTRUMENT COMPANY
408 S. PLYMOUTH COURT, CHICAGO, ILL.

tonation Instruments for o and Aircraft Industries

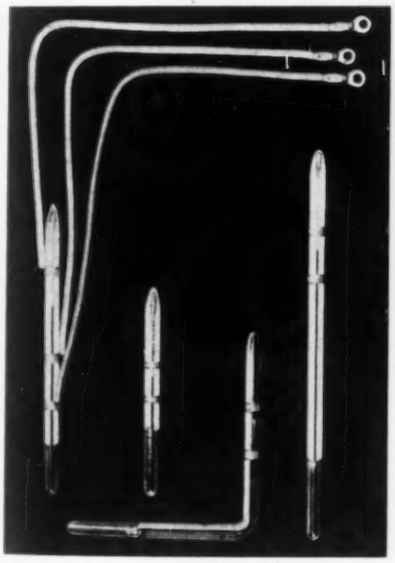
"Electro Detonation Filter and ..." provides means for selecting detonation or other explosion or vibration frequencies in automotive or aircraft engines.



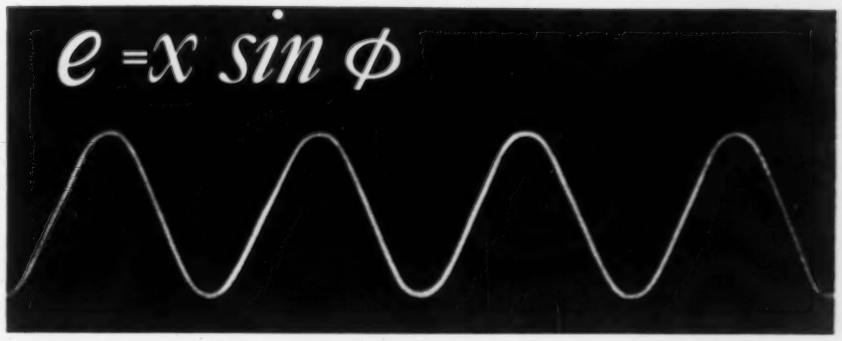
Equipment immediately detects detonation or knock in engine. It is said to tune so closely that only the knock or other desired frequencies to which it is tuned can be heard. Equipment is for use with CFR testing engine, or can be applied to studies with other engines for vibration and explosion phenomena. "Model 2300" Filter covers range from 2000 to 8000 cycles which when used with "Model 3000" Pickup and cathode-ray oscilloscope, immediately indicates presence of detonation. *Electro Products Laboratories, 549 West Randolph Street, Chicago, Ill.*

Mercury-in-glass Thermostats with Sealed-in Contacts

New "Eglas" thermoregulators are available in various forms (some illustrated) and in all the ranges required for ovens, incubators, cold baths, instrument-calibrating baths, etc. Design lends itself to humidity-control applications by adding wicking and water reservoir to assembly. Principal features as listed in announcement:



(1) Each instrument is calibrated against National Bureau of Standards Certified Standard. (2) Vibration and shock-proof: Each instrument is gas-filled under pressure and hermetically sealed, then tested against mercury separation and change of calibration. These tests include both gravity (50 *G*) and Shock Test (250 ft.-lb. blows). (3) Tamper-proof: Each instrument is factory-sealed after setting and calibrating for temperature, specified and marked for control points. (4) Dust, dirt or atmospheric conditions cannot change calibration or interfere with operation as vital elements are hermetically sealed. (5) Sensitivity 0.10°F. between —20°F. and 90°F.—*Electric Glass Co., 56 York Road, Hatboro, Pa.*



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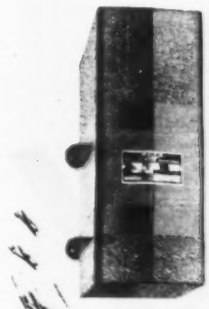

SOLA Constant Voltage Transformers are famous for low distortion . . . *Now* available in units that deliver an almost *Perfect Sine Wave* . . . A regulated source of Constant Voltage, free from harmonic distortion . . . A *final* solution to your voltage regulation problems.

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SOLA CONSTANT VOLTAGE TRANSFORMERS

American War Birds Have Keen Eyes

SEVERAL years ago, at the request of U. S. Army officials, Bausch & Lomb developed a special anti-glare glass for use in bright over-cloud flying. This glass, known as Ray-Ban, has the remarkable property of filtering out excess glare-producing light, at the same time transmitting most of the light useful for seeing. Army, Navy and airline pilots—as well as target shooters and motorists—have welcomed the cool, comfortable, keen vision that Ray-Ban affords.

So, again, and in still another way, Bausch & Lomb gives aid to America's all-out for Victory. Its other contributions, more obvious, include gunfire control equipment—rangefinders, binoculars, aerial height finders. Behind the scenes, but of no less importance, are the instruments of industrial research and production—metallographic equipment, spectrographs, toolmakers' microscopes, contour measuring projectors. Bausch & Lomb eyewear products—eye examination instruments, spectacle lenses and frames—keep a nation of workers at top visual efficiency.

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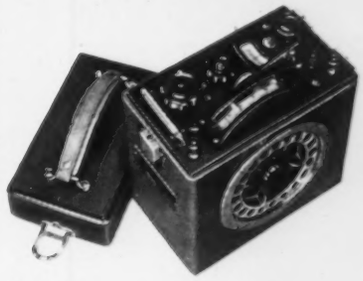

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These Portable Potentiometers are invaluable as instruments for checking temperatures and temperature measuring instruments, as standards for checking all D.C. electric meters, as direct measuring instruments for all D.C. electric values, and as laboratory instruments—where they can be adapted to thousands of precision measuring and checking operations.

Write for free Bulletin No. A502, today.

Wheelco Instruments Co.
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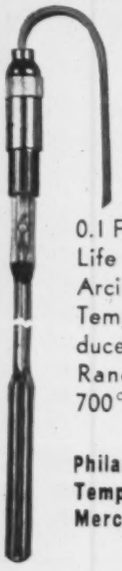
Philadelphia Merc-to-Merc Thermo-Regulators Feature



Mercury to Mercury Contacts : Increased Contact Capacity : Sensitivity within 0.1 F. Exceptionally Long Life and Stability : No Arcing : No Oxidation : Temperature Lag Reduced : Temperature Ranges adjustable to 700°F.

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Philadelphia Merc-to-Merc Temperature Controls and Mercury Plunger Relays

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The Philadelphia Thermometer Co.
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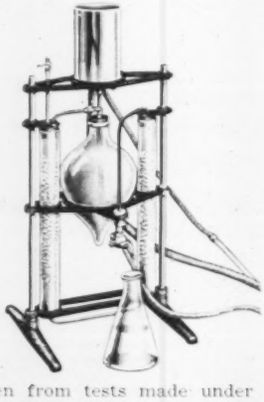
WRITE FOR CATALOGUE No. 104.
Oldest Thermometer Manufacturer in Philadelphia

Submarine Thermometer

New Taylor 5" industrial thermometer, designated as "Submarine Thermometer," is designed for use in a limited space or on equipment subject to vibration. Originally designed for Navy use, this latest addition to maker's line lends itself to Diesel engines, air compressors, lubricating lines on motors, generators or reduction gears, small-diameter brine, steam or water lines, and many other applications. New thermometer's one-piece construction eliminates separate front or top caps which might loosen under vibration; sturdy glass front is held solidly in place by a string bezel, yet comes off easily when desired. Taylor Submarine Thermometer offers two types of separable socket connections, making it exceptionally easy to install and remove; choice of connection offered to suit the application. Available in straight, angle, right side angle, left side angle, or oblique stems to afford best angle position for any location.—*Taylor Instrument Companies, 95 Ames St., Rochester, N. Y.*

Stability Indicator

New and "vastly improved" model of the Enslow Stability Indicator has been completely redesigned to embody features suggested and developed by practical water-



works men from tests made under actual plant operating conditions; is said to provide a continuous corrosivity or stability index with the fewest possible number of operations and minimum time requirement. Two of the improvements which have increased its effectiveness are: a constant-head tank, and a specially designed calcium carbonate contact chamber which holds a charge of precipitated chalk. Water flows through the Indicator continuously. It enters constant-head tank without turbulence, thence flows through a tube which extends down to bottom of $CaCO_3$ contact chamber. Shape of chamber produces a tapered velocity of upward flow to float the chalk "blanket," thus affording effective distribution and intimate contact between water and chalk without danger of sweeping out the light chalk. (In this respect new Indicator resembles the conical-shaped Spaulding Precipitator.) Water passes from top of chamber, flows downward through primary trap tube containing No. 2 calcite sand, thence upward through secondary tube which is filled with No. 1450 grade calcite sand and serves as a trap and decollodizing unit. The completely stabilized effluent from this secondary tube flows to a 2-way cock which permits it to be run into a sampling flask or to waste. Other new features: An air-bleeder on primary trap tube to preclude pressure build-up and possible cracking of the tubes. Adjustable metal clamps which hold rubber stoppers securely in these tubes. Constant-head tank and tubing are of highly polished nickel.—*Phipps and Bird, Inc., Richmond, Va.*

Jones Tachometer

Continuous Indicati

Centrifugal Type

Portable and Stationary

Indicating Speed and Total Run

Flexible Shaft, Belt, or Electric Drives for Remote Indicating.

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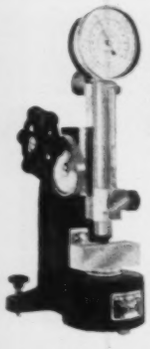
done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 35 years.



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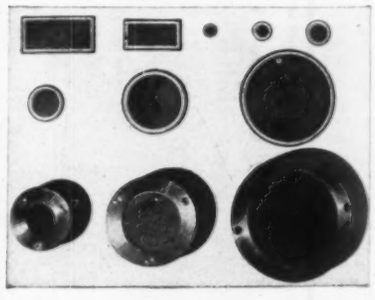
9025 Van Wyck Ave., Jamaica, N. Y.



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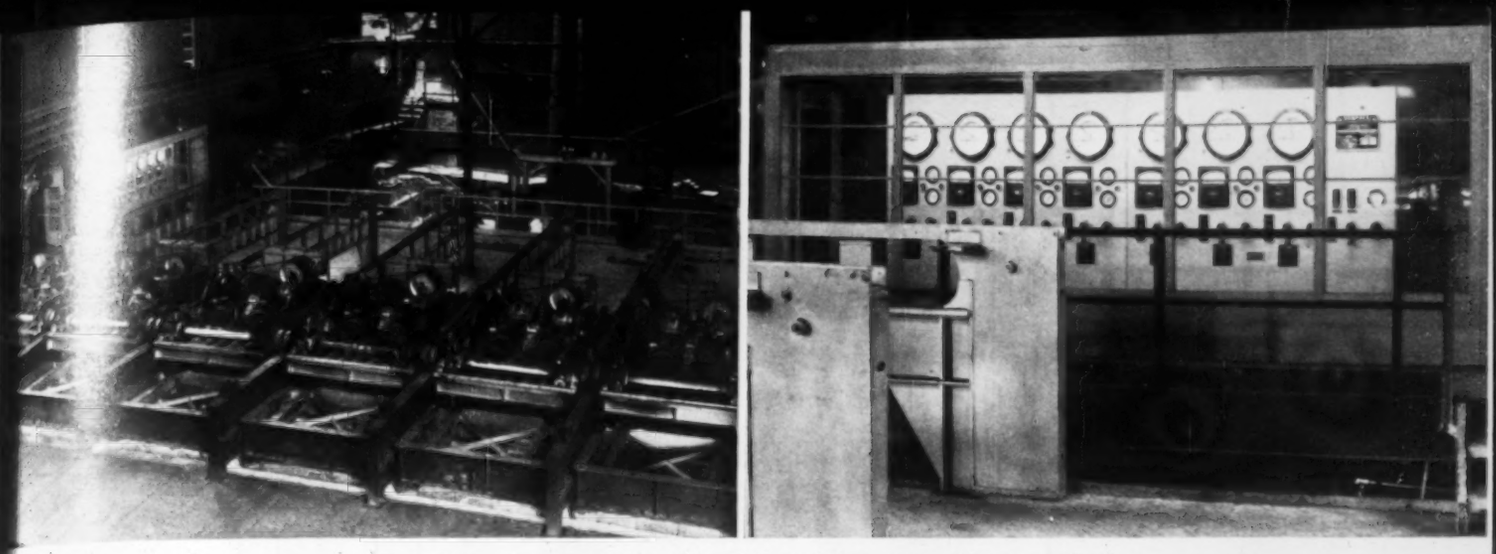
Colorimeters Electronic Timers
Reflectometers Photometers
Fluorescence Meters



General view of a modern soaking-pit installation and close-up view of instrument panel.

Steel Furnace Instrumentation
with Special Reference to Soaking-pit and Open-hearth*

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IN 1922, the railroads (the largest tonnage consumer) took 25% of the steel produced in the United States and the automotive industry 9%. In 1935, the automotive industry consumed 24% of all steel and the railroads only 7¼%. These figures show a trend away from the heavy shapes and towards the auto-body type of product. Demand for this type of product requires steel that will withstand a type of rolling and drawing operation entirely different from that required of the heavy rails, structural shapes, etc.

Today, steel must be made to closer and closer specifications, which in turn require closer attention to its metallurgical and physical treatment. The heating which steel receives in the mill is one of the most important factors determining final product quality; and yet, up to relatively few years ago, it was one of the most neglected. While heating cannot add qualities to the finished steel which are inherently not there, certain heating practices can and do prevent attainment of these qualities in the final product. Realization of this fact has brought about a revolution in the traditional methods of heating, and accounts for the displacement of the old rule-of-thumb practices by the more scientific methods based on instrumentation.

Six years ago, the first successful automatically-controlled soaking pit was placed in operation. Today, no new pits are contemplated without complete complements of measurement and control instruments, and rebuild programs consist mostly of revamping existing installations to permit more precise measurement and control of heating. The same holds true with respect to slab and billet heating furnaces; and the open hearth is rapidly approaching the same point.

If some of the statements we shall make had been made ten, or even six, years ago, some engineers would have agreed in part and still others would have disagreed entirely. The opinions expressed, however, would have been made on the basis of the accumulated experience at their respective plants. Today they might still disagree but they would do so only because they have not had the opportunity to set up the required test equipment and to measure the various factors involved. In other words, facts today would replace opinions. It is the application of instrumentation to metallurgical furnaces which is rapidly changing steel mill heating from a matter of guess and opinion into a science based on measured results.

The general principles underlying the application of measuring instruments and automatic controllers to heating furnaces are quite simple. In actual practice, however, the problem becomes more complex and difficult. It must not be thought that what we have to say in this regard is the acme of perfection. For from it. Actually, the industry is just beginning to make headway, and the completely instrumentized furnace of twenty years hence will be, in all probability, a lot different from the unit we consider the last word today. Present-day practice carries still too many guesses and compromises, and is still far too dependent on the human element to be the ultimate in instrumentation.

In considering instrumentation for any furnace, the problem logically divides itself into three parts paralleling the three variables, other than the physical handling of the steel, which confront the heater in actual practice. These are (1) rate of fuel input, (2) rate of air supply and (3) rate of gas removal.

Rate of fuel input is in a sense the most important and the one most difficult to measure and control in practice. The primary object in any furnace operation is to heat the greatest tonnage consistent with certain standards of quality at the lowest cost. To do this requires first a knowledge of how much fuel to admit. Records have been kept for many years, for example, on producer-gas-fired soaking pits, of the number of pounds of coal required to heat a ton of ingots. Few data, however, until recently, were available on just how fast the fuel should be used.

Since heating is a minute-to-minute process and since the rate cannot be uniform, it does little good from the heater's standpoint to know how much fuel the overall operation will take. Since instrumentation is primarily a tool for the operator, it should provide information of a kind that he can use. Our first requisite, then, would seem to be an indication or record of rate of heat supply. The actual mechanism to use depends, of course, on the kind of fuel. For gaseous fuels, an orifice or Venturi tube, together with a suitable secondary element, would be the choice; for liquid fuels, either a displacement or orifice type meter could be used; for solid fuels, such as powdered coal, a displacement type element would be the answer.

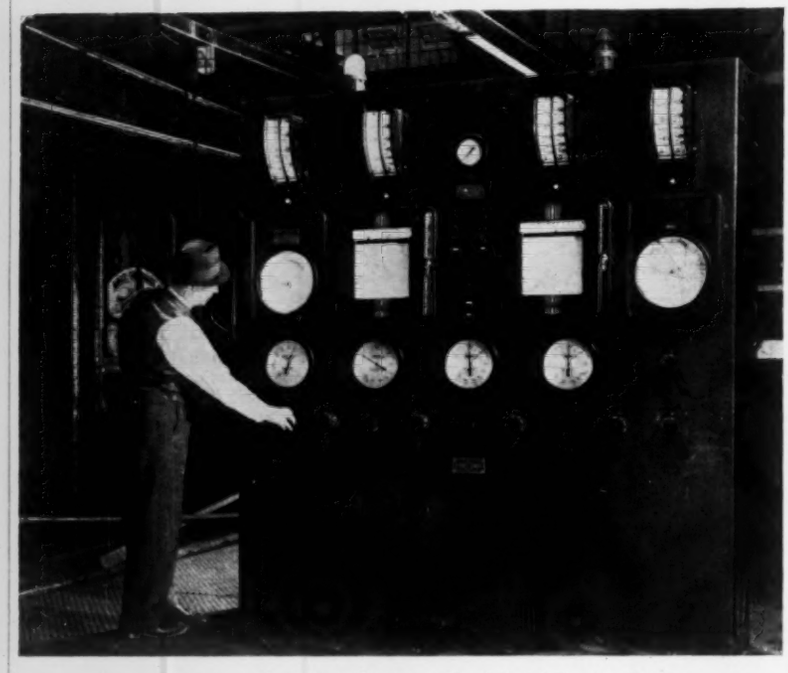
Since it is expected that the heater will have to change the heat input from time to time, the second requisite would be a means for effecting the change. This would take a form of a valve, rheostat, or some other suitable mechanism.

Having now a means for changing fuel firing rate, and an indication of the prevailing rate of flow, the next question is how much heat input to supply. Since the primary

*From the text of a lecture before the American Society for Measurement and Control, Pittsburgh.

function of a furnace is to heat steel to certain temperatures, the logical answer would seem to be to measure the steel temperature and regulate accordingly. In certain annealing operations, at relatively low temperatures, this is solved simply by installing thermocouples in contact with the work.

When the furnace in question is a soaking pit, however, the idea of installing thermocouples in the work immediately strikes a snag. The temperature to which it is desired to heat the work is high—close to that which would be ruinous to the steel. It is in fact too high for practical thermocouple practice; secondly, the number of units comprising the work is such that their disposition within the pit furnace prohibits the use of anything like a single thermocouple. A spot radiation reading on any particular ingot



Control panel of a modern instrumentized slab heating furnace.

would not mean much either, because of the physical size of the ingot and the fact that different parts of the ingot, when exposed to firing, are at different temperatures. Obviously, a spot reading would not do. The next suggestion would probable be to use the pit temperature as a guide and fire at such a rate that the pit temperature never exceeds the desired value. This sounds fine, but the question comes up as to just what is pit temperature; an imaginary traverse in three dimensions would show that the actual temperature varies throughout the pit: from end to end, from side to side, and from top to bottom. Which of these temperatures should be selected as the right one to judge the rate of firing? If this imaginary temperature traverse were made at different firing rates, we probably would find also that the temperature relations at various spots would change, and the point of highest temperature would move about depending on the path of the flame and the products of combustion and, finally, also on the number and location of ingots within the pit.

Although the problem is quite complicated, there are practical solutions, the most common one being to select a spot in the pit that most nearly bears a constant relation to the combined pit and ingot temperature, and to control from this point.

This, too, has its limitations. Suppose, for example, that the pit is charged with cold steel. Since the charge has cooled the pit, the heater may increase the firing rate to the maximum which the available furnace volume can burn effectively and, while the flame temperature may be higher than the safe ingot skin temperature, the ingots are not harmed because heat flows from the outside shell to the interior at a rate sufficient to keep the ingot skin below the danger point. As the ingots come up to temperature, the rate of heat transmission from exterior to interior decreases, and more of the heat goes into the pit structure itself, raising the temperature and, in doing so, gives the heater an indication that he should reduce the firing rate. With ingots charged hot, the ingot skin reaches the maximum temperature quicker than the pit walls and with a higher firing rate it is quite possible to wash or burn the steel before the heater gets any indication of danger. The answer here is to determine by test the relation between the temperature of our selected point and the maximum firing rate for steels of various temperatures, and to instruct the heater accordingly. Everything considered, the problem of giving the heater an indication of how much fuel to fire, and at what period of the heat, is a difficult job—especially on a batch type heating furnace.

Another solution to this problem involves measurement of both the highest and lowest temperatures within the pit. The highest temperature is usually that of the cover or a wall, and the lowest the temperature of the escaping flue gases. We know that if a pit is charged with steel and heat applied, the steel will absorb the heat until it is uniformly up to temperature equal to that of the pit itself. It is then possible to reduce fuel input to offset radiation losses and maintain the steel and the pit at the desired points. If the heater knows that he has never exceeded a certain temperature at the highest point in the furnace, and knows further that the steel at the end is above a certain minimum temperature, he can safely assume that he has correctly regulated his fuel input to produce the desired final results; namely, uniformly heated steel at the desired temperature.

On continuous furnaces, the problem of how much fuel to fire, and when, is similarly determined by temperature measurement at a selected point in the furnace, although the problem here is considerably simpler.

On open-hearth furnaces, again, we are confronted with the problem of gaging heat input requirements, although the consensus among operators seems to be to use as high a temperature as possible without excessive damage to the furnace itself. This involves firing so as to keep the temperature of a selected spot in the furnace not higher than a value which experience has shown to be most economical.

After considering all of these points, it is a wonder that the heater, in the past, has been able to do as good a job as he has without the aid of instruments for so long a time. His past shortcomings would readily be pardoned if we would but place ourselves in his shoes.

The second step in instrumentation is *Rate of Air Supply*. We are all familiar with the facts that (1) if too little air is admitted the fuel is not completely consumed and the heat input expected for any given rate of fuel flow is not realized; and (2) if too much air is supplied, heat passes up the stack rather than into the work, with consequent reduction in tonnage and increase in fuel cost. In addition, another factor of importance must be considered: Since steel is heated to elevated temperatures, oxidation is rapid and is dependent to no small extent on the nature of the furnace atmosphere, whether neutral, oxidizing, or reducing.

As before, instrumentation here involves first an indication of how much air is being supplied; second, a means for adjustment of rate of air flow; and third, an indication of how much to supply. If a steel mill furnace were hermetically sealed with a single air inlet, and a fan to force the air in under pressure, the measurement of how much air is being supplied could be effected simply by an orifice or Venturi tube properly located according to known rules, in the line between fan and burners. Unfortunately, some steel mill furnaces are massive affairs, made of steel and refractories and are operated at temperatures which are close to the maximum which commercially practicable refractories can stand. Flue passages, such as those in an open-hearth furnace, are long and are subjected alternately to heating and

ng, with the result that thousands of cracks eventually crop. When it is considered that a hundredth of an inch differential pressure is sufficient to create a velocity of 400 feet per hour, it is readily apparent that a considerable amount of air can leak into a furnace without any chance for a gage to show it. On some open-hearth furnaces, as much as 60% of the total air used for combustion has come from a source other than the combustion air fan. Obviously, under such circumstances, a measurement of air supply is of little value. Then, too, since air can leak in before combustion takes place, as well as after, a flue gas analysis of the waste gas is of little help.

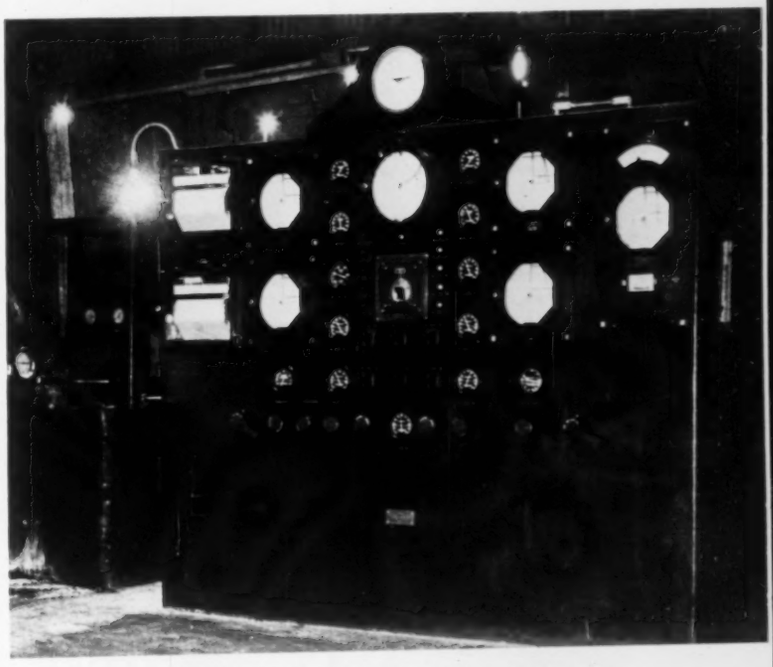
The most successful system to date has been to arrange the burners on the furnace for forced air supply, install an orifice meter in the air supply line, and operate the furnace under pressure to minimize the effect of air infiltration. A damper or other means for control of flow permits adjustment of the air supply rate.

Having a means of measurement and adjustment, the next question is how much air to supply. In some types of furnaces, it is agreed upon, while in others there is difference in opinion. Take the soaking pit for example: before the advent of measurement and control, it was generally supposed that a smoky flame was best on the theory that a reducing atmosphere would form less scale than any other. However, since meters and controls have generally been used, it is quite well agreed among engineers now that a reducing atmosphere, in addition to wasting fuel, is not desirable for other reasons. The scale formed on the ingot is thin and tight and has a tendency to roll into the steel, with resulting surface markings in the final product. On the other hand, the scale formed with an oxidizing atmosphere is porous and, while it is thick, it largely falls off while the ingot rattles along on its way to the mill and is completely off after the first few passes. The resulting surface in the rolled product is smooth and free of blemishes. It is generally agreed now that for most steel mill furnace work with open flames, air flow should be controlled in a definite ratio to fuel flow so as to provide at all times a few percent of free oxygen in waste gases, thereby assuring maximum temperatures and economical use of fuel.

In the case of open-hearth furnaces, however, there is still a difference in opinion as to whether the rate of air supply should be regulated according to rate of fuel flow or according to some other factor. As more and more furnaces are equipped with measurement and control instruments, it will be possible at some future date to have pretty complete agreement on this point. At the present time, it seems desirable that the rate of air supply to an open-hearth furnace be regulated in accordance with rate of fuel supply during the melt-down period, and according to the best judgment of the operator during the refining of the heat. This is not an admission of failure on the part of instrumentation, but simply that experience has not been great enough to prove definitely one way or the other as to how rate of air supply should be regulated during the refining period of the heat.

The third step in furnace instrumentation involves *Removal of Products of Combustion*. As covered previously, it is desirable to adjust the outlet damper to maintain a positive pressure within the furnace to eliminate air infiltration; however, too high a pressure within the furnace causes flame sting-outs around the doors and peepholes, and makes working conditions quite unbearable. Also, too high a pressure increases refractory maintenance. It therefore is desirable to control the removal of products of combustion so as to maintain a positive pressure as close to atmospheric as possible. Since some steel mill furnaces may be twelve feet high or more, the point at which the pressure is measured becomes important because of the large difference in density between the atmosphere within a furnace and that outside. The furnace acts as a chimney and, while a pressure may exist at the roof, a considerable suction may be present at the hearth level. The reference point to be selected is that where the actual value of pressure usually corrsponds to a balanced condition at the hearth level.

Where a furnace is completely encased and free from leaks, the regulation of the removal of products of combustion is accomplished so as to preserve the direction of the flow of products of combustion from the burners to the outlet. For example, suppose maximum firing rate on a totally-enclosed furnace, with the furnace damper so arranged that the flow of products of combustion substantially fills the total furnace volume. If the firing rate is decreased considerably without a corresponding decrease in damper opening, the flow of products of combustion tends to take the path of least resistance between firing port and furnace outlet and, in doing so, may not reach the parts of the furnace most distant from the burner. In this way, the work more in line between the burner and the pit outlet will be overheated, while the steel farthest away from the



Control panel of modern instrumentized open-hearth furnace.

burner will be underheated. By closing down on the damper at the lower firing rate, the products of combustion can be made to assume different paths through the furnace depending on the opening of the outlet damper. In several commercial installations, the outlet damper is regulated with firing rate, according to some precalibrated sequence rather than from the pressure existing within the furnace.

Bringing our discussion to a point, we would say that our instrumentized furnace would carry a centralized panel with the following equipment:

1. *Heat Input:* Instruments to indicate or record
   (a) Total fuel flow to furnace.
   (b) Distribution of fuel among burners.
   (c) Furnace temperature.
2. *Air Supply:* Instruments to indicate or record
   (a) Total air flow to furnace.
   (b) Distribution of air among burners.
3. *Furnace pressure* indicator or recorder.
4. *Fuel flow control* at panel, preferably automatic from temperature indication.
5. *Air flow control*, preferably automatic from fuel-air ratio, with means for adjustment of ratio from panel.
6. *Stack damper control*, automatic from furnace pressure, with means for setting the pressure to be maintained.

From our consideration of instrumentation of steel mill furnaces so far, it is apparent that the methods proposed are revolutionary only in that the judgments as to "how much" are made not on the variable element of the human guess but on an exact measurement of the quantity involved, which measurement will be the same Monday as it will be on Thursday, today as well as a year from now. It has always been the experience that the installation of

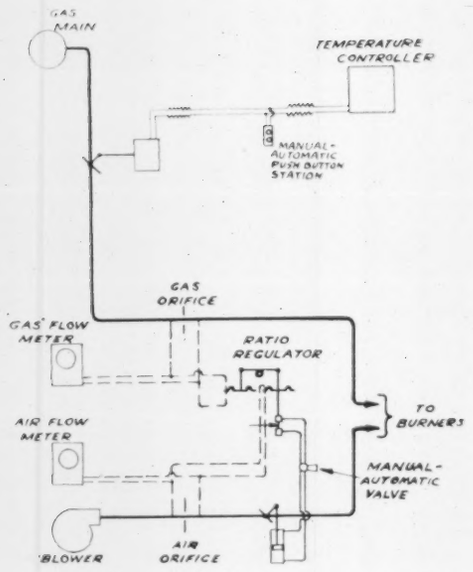


Fig. 1. Diagram of fuel input and fuel-air ratio control for a stable gaseous fuel.

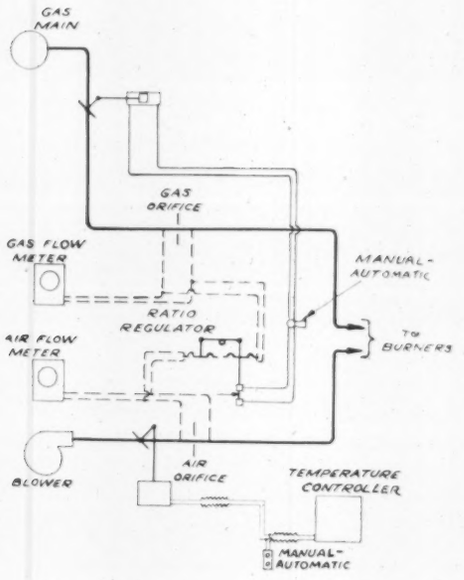


Fig. 2. Diagram of control system similar to Fig. 1, but with heat input control in air supply instead of fuel supply.

measurement and control instruments has, for the first time, permitted engineers to learn what the necessary conditions are to produce the heating results desired and to permit experiment to determine how the results can be improved. Having once determined what is the one best way for a given installation, automatic controls set to reproduce these conditions will assure continuous reproduction of results far more uniformly and consistently than has been possible before. The attention the steel industry has paid to instrumentation in the past few years proves our point.

The following figures illustrate practical application of the control principles discussed above:

Fig. 1 shows fuel input and fuel-air ratio control on a furnace burning a stable gas fuel. The furnace pressure controller, while not shown, is understood to be a part of the system. The rate of heat input is determined by the operation of the temperature controller, which commands a control valve in the gas line to the furnace.

Air flow is controlled in accordance with gas flow by means of a ratio regulator which utilizes the pressure drop across orifices in the gas and air lines to the burners. The ratio regulator operates the butterfly valve in the air supply line to maintain a balance between the air orifice differential pressure and the gas orifice differential pressure. In this manner, air flow is regulated in accordance with gas flow.

Fig. 2 shows a similar application except that the temperature controller adjusts the air flow to the burners rather than the gas flow as shown in Fig. 1. The air-gas ratio regulator responds to metering orifices in the air line and in the gas line to the burners; and it commands the gas control valve as required to maintain the proper ratio between gas flow and air flow.

Fig. 3 shows a control system which is a combination of the two previous schemes. The fuel input control consists of a temperature controller which commands two valves, one in the gas and the other in the air line to the burners. The two valves are linked together either mechanically or pneumatically and are, in fact, variable-area orifices. A ratio regulator measures the pressure drop across the air valve and regulates the flow of gas so that the pressure drop across the gas valve is maintained in direct proportion. A controller such as this will give accurate regulation over an extremely wide range in fuel firing rates.

On an increase in firing rate, the furnace pressure will tend to increase, and conversely; but the furnace pressure

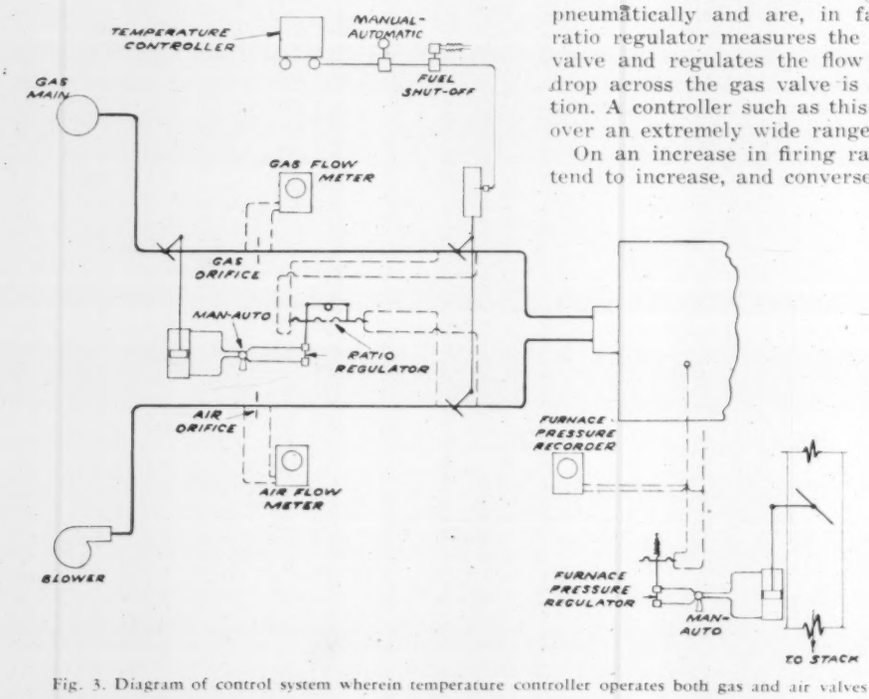


Fig. 3. Diagram of control system wherein temperature controller operates both gas and air valves simultaneously.

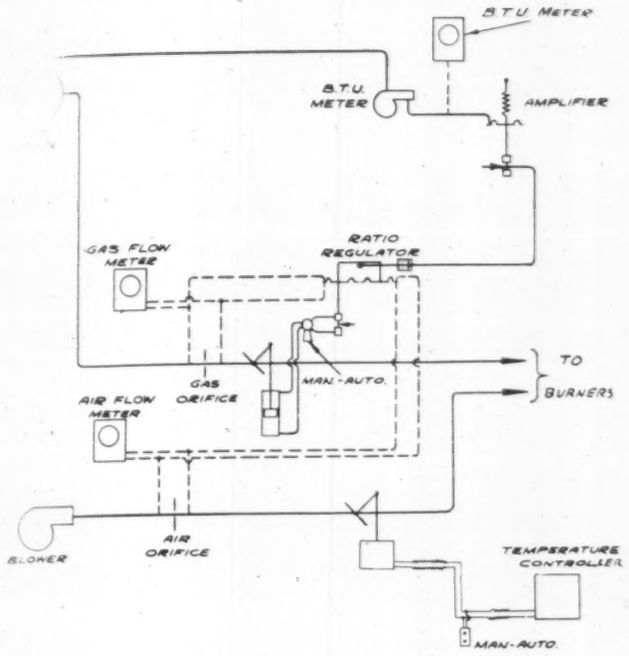


Fig. 4. Fuel input and fuel-air ratio controllers applied to a furnace fired by a gas fuel of varying calorific value.

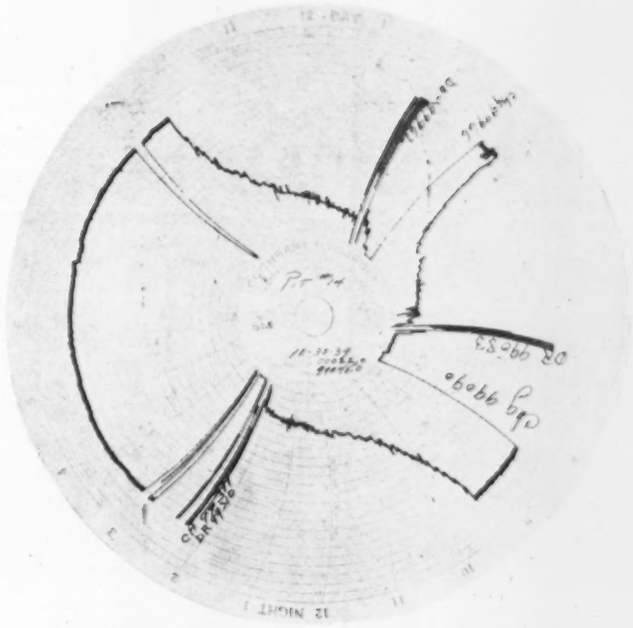


Fig. 4a. Gas flow chart record taken from furnace equipped with control system shown in Fig. 4.

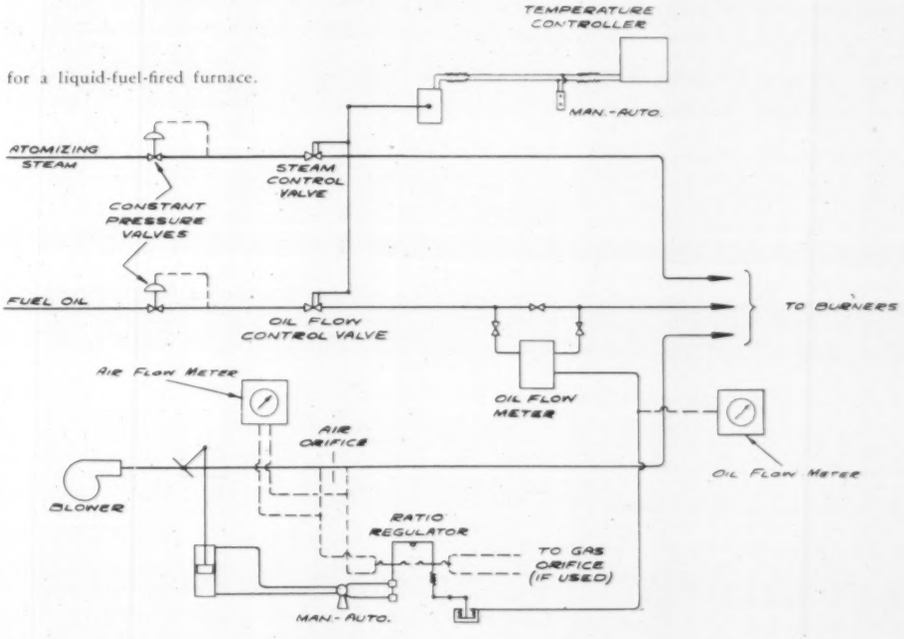
regulator adjusts the opening of the stack damper to maintain the desired pressure within the furnace.

Whereas the control schemes discussed previously apply to installations using a stable gas fuel, the control scheme shown in Fig. 4 applies to an installation where the heating value of the gas may vary. As in Fig. 2, the temperature controller commands the burner air control valve; and—likewise as in Fig. 2—the ratio regulator controls the gas flow in accordance with some predetermined ratio to air flow. Since the calorific value of the gas may vary, the ratio of gas to air is changed automatically to compensate for the difference in the heating value of the gas. To accomplish this change automatically, a B.t.u. meter, utilizing either heating value directly or the density of the gas as a primary indication, generates a loading pressure (either pneumatic or hydraulic) to position the ratio adjusting mechanism of the gas-air ratio regulator. The various positions of the ratio mechanism are calculated beforehand and the B.t.u. correcting equipment calibrated to provide the desired ratios for the different qualities of gas used.

Fig. 5 shows a typical arrangement for an oil-fired or tar-fired furnace. Here, the fuel input control consists of a temperature controller operating steam and oil flow control valves ganged together through a calibrated range. Since the steam and oil control valve positions are used as an indication for controlling the ratio of atomizing steam to fuel oil, it is necessary that constant pressure regulating valves be installed ahead of these control valves. For air flow control, an oil flow metering element is installed in the oil line to the burners and generates a loading pressure (pneumatic or hydraulic) proportional to the rate of flow of oil. This loading pressure is impressed on the ratio regulator which commands the air flow control valve. In this manner, air flow is regulated in accordance with oil flow.

Fig. 6 shows a control arrangement applied to a pulverized coal fired furnace. The fuel input control consists of a temperature controller which commands the butterfly valve in the air supply line to the burners. The rate of air

Fig. 5. Control layout for a liquid-fuel-fired furnace.



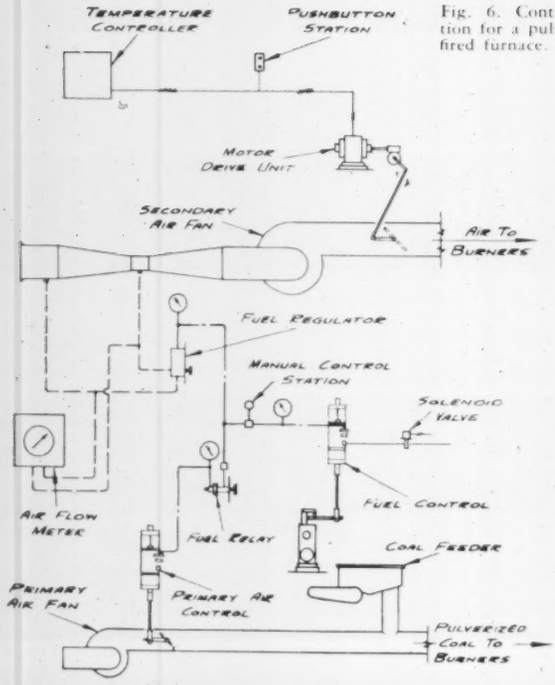


Fig. 6. Control application for a pulverized-coal-fired furnace.

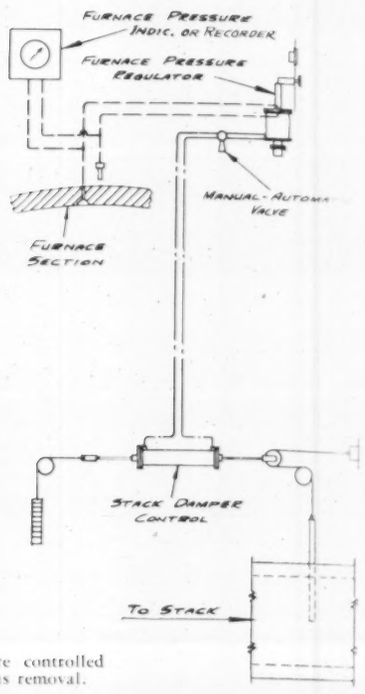


Fig. 7. Furnace pressure controlled by controlling rate of gas removal.

flow thus established is measured by means of a Venturi tube in the air line. A fuel regulator, responding to this Venturi, generates a loading pressure (pneumatic or hydraulic) which is an indication of the rate of air flow. This loading pressure is transmitted to the coal feeder and primary air controls where the rate of coal feed is adjusted to match the rate of air flow.

Control of rate of gas removal is similar to that previously described in that the pressure within the furnace is utilized for regulation. See Fig. 7. The furnace pressure regulator commands the stack damper by means of an oil power cylinder to maintain the desired pressure within the furnace.

Fig. 8 shows an installation of control applied to a reversing type furnace burning a stable gaseous fuel. The control is similar to that shown in Fig. 1 with the addition of a reversing control mechanism. To effect control of reversal, a time cycle controller is adjusted to provide contacts at the desired time intervals. These contacts operate a program unit which consists of a motor-driven camshaft carrying a series of cam-operated pilot valves. Two of the pilot valves are used to open and close alternately spring loaded diaphragm-actuated valves in the gas supply lines to opposite ends of the furnace; likewise, two other pilot valves operate in conjunction with diaphragm type spring loaded valves in the air supply lines to opposite ends of the furnace. The gas and air reversing valves to one end of the furnace are both open at the same time while the two valves to the opposite end of the furnace are closed. After completion of the firing interval, all open gas and air valves are closed and the previously closed gas and air valves are opened through the operation of the pilot valves. Direction of firing is thereby reversed. For control of furnace pressure, it will be noted that the same valves in the flue ducts are utilized both for reversal and control. Power cylinders attached by means of cables to the corresponding dampers are connected alternately to the source of hydraulic pressure for closing and to the furnace pressure regulator, which also utilizes hydraulic pressure as a motivating force, for opening. The regulator automatically adjusts the opening of the outgoing flue damper to maintain the desired pressure within the furnace.

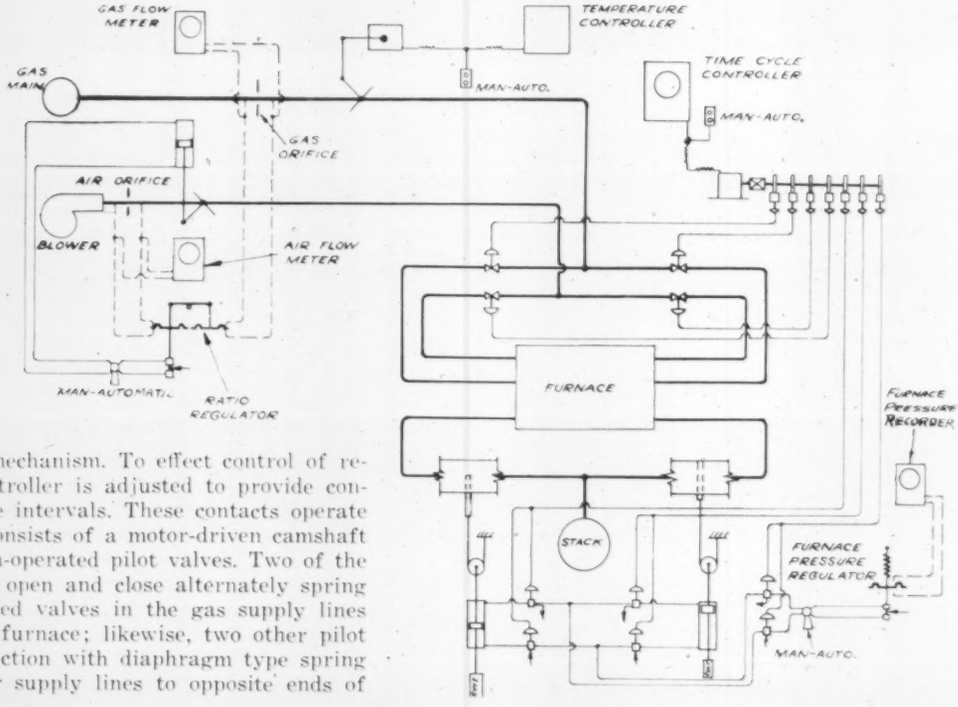


Fig. 8. Control layout for a reversing type furnace fired by a stable gaseous fuel.

Repair or Replacement of Old Electrical Instruments—Some Influencing Factors

By PAUL MacGAHAN
Electrical Engineer, Westinghouse Electric & Mfg. Co., Newark, N. J.

WHETHER to attempt repairs of an old electrical instrument or to replace it with a modern type—that time-honored question—has been again brought to the fore by present difficulties in obtaining priority for new replacements.

Thus, under these conditions, the series of articles by Mr. James Spencer covering maintenance and repairs is of timely interest. But it may be useful nevertheless, at this time, to review some of the underlying considerations involved.

In arriving at a fair appraisal value of old apparatus, even assuming that it is in good working condition, the factors of obsolescence are involved.

The rate of depreciation of instruments is, of course, much less than for various types of machines, an extreme example of which is the automobile. Good instruments become obsolete, however, by feeling the effects of development improvements in design. Instrument engineers are not content to let well enough alone, but are continuously improving performance, and effecting cost reductions.

Thus, for example, an induction type nine-inch diameter wattmeter of previous days is less accurate, takes much more room, and was far more expensive than an indicating wattmeter of the present type.

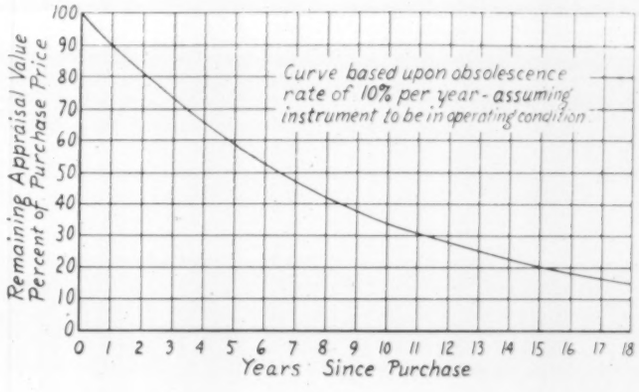


Fig. 1 indicates the present appraisal value of an old instrument assuming a 10 percent rate of depreciation and obsolescence when the instrument is still in operating condition. As time goes on, there ordinarily becomes less and less economic basis for repairs. Repairs may cost too large a proportion of, or be more than, the remaining appraisal value. Replacement parts may have become too expensive or even no longer kept available from the manufacturer. The manufacturer's responsibility for supplying repair parts has been expressed as follows in the N.E.M.A. Handbook of Apparatus Standards:

> The ethics of modern business seem to recognize the principle that the manufacturer assumes an implied but nevertheless rather definite responsibility for holding himself in readiness to furnish such usual repair and supply parts for any machine (or instrument) built and sold by him, as will probably be needed by his customers, at reasonable prices and on prompt delivery.
>
> The duration of the period within which such provision shall continue varies greatly with different manufacturers and no approximation to a general rule or practice has ever been developed so far as we are aware. In that branch of manufacture with which the N.E.M.A. is most closely identified, development of new machines, methods of manufacture and application of these machines in industry are exceedingly active and a device or machine which is standard today may be obsolete tomorrow. The development of all the material instrumentalities of the industry is largely in a state of flux, hence it is inevitable that in the aggregate a vast amount of the output of our factories, in effect, undergoes obsolescence within a certain time after it is sold, and is superseded before it would have really reached its full term of service by reason of the wear and tear of use.
>
> This constant change in product with the implied obligation for providing repair and supply parts for all the many and various sizes, types and modifications of motors, generators, control and other electric power apparatus supplied to one's customers, imposes a constantly increasing burden upon the manufacturer, and the more active and progressive he is in adopting improvements and enlarging his lines, the greater becomes his difficulty and expenses in providing and maintaining that service to customers which is so highly essential for insuring the continuous and normal operation of the electrical machinery upon which they rely for the power and light required in their plants.
>
> Correspondence with manufacturers in kindred lines indicates that it is usual practice to continue provision for the prompt supply of repair parts for periods ranging from three to five years beyond the time at which machines have been superseded, and nearly all are prepared to furnish such parts for an indefinite period after the machines themselves are no longer manufactured but on such shipment and at such prices as are applicable to job work.
>
> It seems to be the fairly general opinion that the special tools used in the manufacture (and any remaining stock of parts) may be discarded at the end of a two- or three-year period, after a given type of motor, generator, control, etc., has been superseded, the theory being that if the owner of the equipment has charged off adequate depreciation from year to year, he should be in a position to purchase and desire to purchase new and up-to-date equipment when the old has become obsolete.

There are many opinions as to the average useful life that may be assigned to a general-purpose motor or generator, receiving ordinary care and attention. Taking into consideration wear and tear, and obsolescence by reason of advances in design and construction, perhaps a life of twelve to fifteen years is conservative. Many motors have been in service twenty and twenty-five years, and many have gone to the scrap heap in five or six years, or even sooner, but twelve years seems a fair average. (Instruments like time-pieces will last much longer. For instruments which have been carefully bought, maintained and used, an obsolescence rate of 10 percent may seem to be about right). If this be true, then possibly the obligation of the manufacturer to supply repairs and renewal parts based upon manufacture in reasonable quantity may cease five years after a type becomes obsolete, but he should still be prepared to give such service on some proper basis, taking into consideration the special nature of the service, until the demands for repairs or renewals have sunk to negligible proportions, indicating that the machines themselves have been worn out or scrapped.

The older instrument manufacturers are more inclined to lean over backwards to maintain records and facilities for repairing or supplying replacement parts. They are disinclined to recommend that modern styles be substituted instead of repairs, for fear that their motives may be misunderstood. They would, however, be doing their customers a real service in pointing out cases where repairs would constitute throwing a dollar after a bad penny.

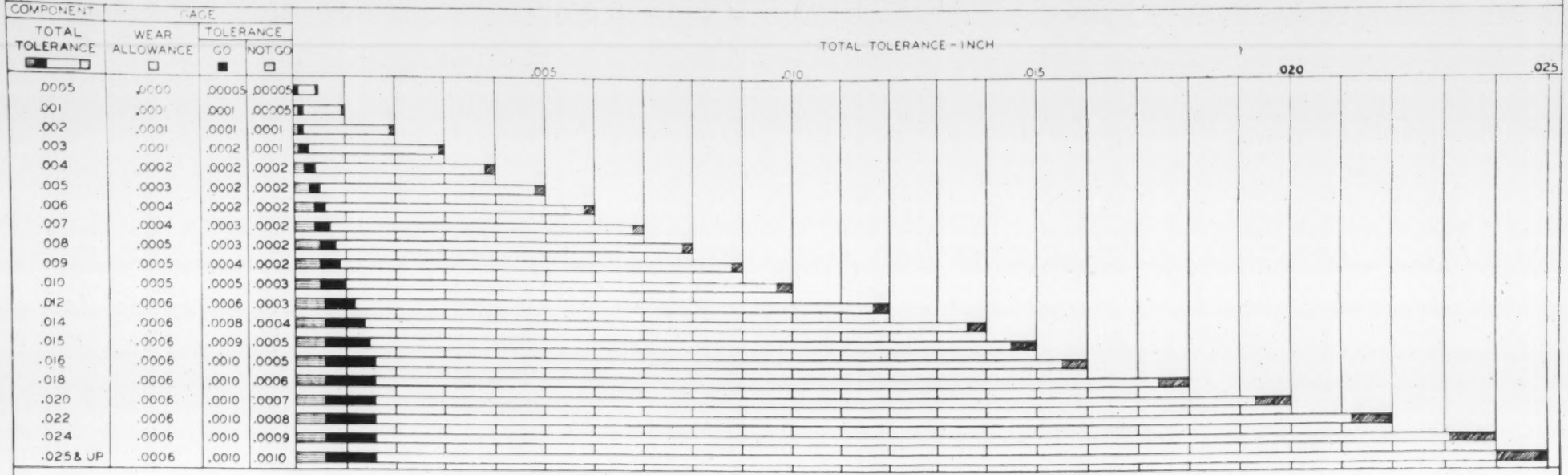
On the other hand, it may be easier for a user to get appropriations out of maintenance accounts than to finance the purchase of new equipment. Another consideration often met with, in switchboard instruments, is that of changing the drilling or connections to take new instruments, or that of matching the appearance of the older types. The latter considerations do not hold in the case of portable instruments.

Still another consideration is in the cases where there is a maintenance organization which can function on repair work, as well, without a special cost accounting for the time expended.

Then there is the question of whether the repairs are such as can be readily handled locally, or whether they are such that the manufacturer's jigs and special tools are needed to do a satisfactory job. Modern instruments depend almost entirely on tool equipment for their fabrication and assembly, and some parts would be very difficult to repair or reproduce locally.

WEAR ALLOWANCES AND GAGEMAKERS TOLERANCES, PLAIN PLUG AND PLAIN RING INSPECTION GAGES INCLUDING PLAIN RING GAGES FOR MAJOR DIAMETER OF SCREWS, AND PLAIN PLUG GAGES FOR MINOR DIAMETER OF NUTS

COMPONENT	GAGE		
TOTAL TOLERANCE	WEAR ALLOWANCE	TOLERANCE GO	TOLERANCE NOT GO
.0005	.0000	.00005	.00005
.001	.0000	.0001	.00005
.002	.0001	.0001	.0001
.003	.0001	.0002	.0001
.004	.0002	.0002	.0002
.005	.0003	.0002	.0002
.006	.0004	.0002	.0002
.007	.0004	.0003	.0002
.008	.0005	.0003	.0002
.009	.0005	.0004	.0002
.010	.0005	.0005	.0003
.012	.0006	.0006	.0003
.014	.0006	.0008	.0004
.015	.0006	.0009	.0005
.016	.0006	.0010	.0005
.018	.0006	.0010	.0006
.020	.0006	.0010	.0007
.022	.0006	.0010	.0008
.024	.0006	.0010	.0009
.025 & UP	.0006	.0010	.0010



GAGEMAKERS TOLERANCE, FLUSH PIN AND ADJUSTABLE SNAP GAGES.

.0005		.00005	.00005
.001		.00005	.00005
.002		.0001	.0001
.003		.0001	.0001
.004		.0002	.0002
.010		.0003	.0003
.015		.0004	.0004
.020 & UP		.0005	.0005

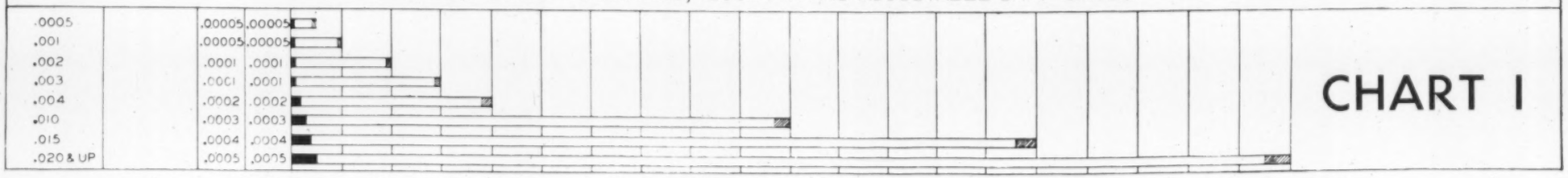


CHART I

This chart shows, both numerically and graphically, wear allowances and gagemakers' tolerances for inspection gages. For component tolerances not listed, the next smaller tolerance shall be used.

The first four columns show numerical values, while the following portion of the table shows graphic values. Column 1 shows the total tolerance on the product. Column 2 the wear allowance on the "go" gage. Column 3 the tolerance on the "go" gage, and column 4 the tolerance on the "not go" gage. There is no wear allowance on the "not go" gage because it wears toward the "go" gage and in the direction of safety.

This combination table and chart shows the distribution of wear allowances and gagemakers' tolerances as practiced by the Ordnance Department, U. S. Army, in the design of plain plug, plain ring, flush pin and adjustable snap gages.

The chart is based upon component tolerances and completes almost the entire range of tolerances which will appear on component parts requiring gaging.

Graphically it illustrates the comparatively small portion of the component tolerances which is utilized for wear allowances and gage makers' tolerances. The reader should bear in mind that he probably will not use all of the gage makers' tolerances.

Logically, the table shows no wear allowance for flush pin gages and adjustable snap gages since these are readily adjusted when they wear out of tolerance. Note that wear allowances appear only on the "go" element of gages since wear on the "not go" elements will bring them farther into the component tolerance and decrease rather than increase component tolerance. The "not go" gage wears in the direction of safety.

The allowances and tolerances shown on this chart are the design allowances and tolerances of Army inspection gages. As noted in Chapter I, manufacturing gage wear allowances and tolerances are added on the basis of the 20% Rule. It is the opinion of the author that on component tolerances of 0.001" and less, differentiations between inspection gages and manufacturing gages are impractical.

Tables 1 and 2, referring to thread inspection gages, present sufficient data to design thread gages for the inspection of sixty-degree threads as used by the Ordnance Depart-

TABLE NO 1

THREAD INSPECTION GAGES, DATA, ALLOWANCES, TOLERANCES.

...CH	ROOT CLEAR P/4 NOT GO THREAD RINGS & PLUGS & ALL CHECKS	ROOT CLEAR P/8 GO THREAD RINGS & PLUGS	LEAD ALLOWABLE VARIATION IN CLASS 1 2 3 ⊕	½ ANGLE TOL. ON		PITCH DIAMETER ALLOWANCE		PITCH DIAMETER TOLERANCE		MAJOR DIA THD PLUGS & MINOR DIA THD. RINGS	
				CLASS 1 & 2 GO	CLASS 3 GO & CLASS 1 2 3 NOT GO ⊕	CLASS 1 & 2 GO	CLASS 3 & 4 GO & ALL NOT GO	CLASS 1 & 2 GO	CLASS 3 GO & CLASS 1 2 3 NOT GO ⊕	CLEARANCE NOT GO ONLY	TOLERANCE GO & NOT GO
2	3	4	5	6	7	8	9	10	11	12	13
32	.025	.003	.002	.0002	0°-45'	0°-30'	.0001		.0002	.0002	.0024	.0003
30	.039	.004	.002	.0002	0°-45'	0°-30'	.0001		.0002	.0002	.0027	.0003
28	.056	.004	.002	.0002	0°-45'	0°-30'	.0001		.0003	.0002	.0030	.0004
26	.0179	.005	.002	.0002	0°-45'	0°-30'	.0001		.0003	.0002	.0035	.0004
24	.0208	.005	.003	.0002	0°-45'	0°-30'	.0001		.0003	.0002	.0041	.0004
22	.0227	.006	.003	.0002	0°-30'	0°-20'	.0001		.0003	.0002	.0045	.0004
20	.0250	.006	.003	.0002	0°-30'	0°-20'	.0001		.0003	.0002	.0050	.0004
18	.0278	.007	.004	.0002	0°-30'	0°-20'	.0001		.0003	.0002	.0056	.0004
16	.0312	.008	.004	.0003	0°-20'	0°-15'	.0001		.0003	.0003	.0064	.0004
14	.0357	.009	.004	.0003	0°-20'	0°-15'	.0002		.0003	.0003	.0072	.0005
12	.0417	.010	.005	.0003	0°-20'	0°-15'	.0002		.0003	.0003	.0085	.0005
20	.0500	.012	.006	.0003	0°-20'	0°-15'	.0002		.0003	.0003	.0103	.0005
18	.0556	.014	.007	.0003	0°-15'	0°-10'	.0002		.0003	.0003	.0115	.0005
16	.0625	.016	.008	.0003	0°-15'	0°-10'	.0002		.0004	.0003	.0129	.0006
14	.0714	.018	.009	.0003	0°-15'	0°-10'	.0002		.0004	.0003	.0149	.0006
13	.0769	.019	.010	.0003	0°-15'	0°-10'	.0002		.0004	.0003	.0161	.0006
12	.0833	.021	.010	.0003	0°-10'	0°-10'	.0002		.0004	.0003	.0174	.0006
11	.0909	.023	.011	.0003	0°-10'	0°-10'	.0002		.0004	.0003	.0191	.0006
10	.1000	.025	.012	.0003	0°-10'	0°-10'	.0002		.0004	.0003	.0211	.0006
9	.1111	.028	.014	.0003	0°-10'	0°-10'	.0002		.0005	.0003	.0234	.0007
8	.1250	.031	.016	.0004	0°-5'	0°-5'	.0002		.0005	.0004	.0264	.0007
7	.1429	.036	.018	.0004	0°-5'	0°-5'	.0002		.0005	.0004	.0302	.0007
6	.1667	.042	.021	.0004	0°-5'	0°-5'	.0003		.0005	.0004	.0353	.0008
5	.2000	.050	.025	.0004	0°-5'	0°-5'	.0003		.0005	.0004	.0425	.0008
4½	.2222	.056	.028	.0004	0°-5'	0°-5'	.0003		.0005	.0004	.0473	.0008
4	.2500	.062	.031	.0004	0°-5'	0°-5'	.0003		.0006	.0004	.0532	.0009

MAY BE SHARP V — ALL ZERO

⊕ FOR CLASS 4 SEE N.S.T.C. REPORT 1933 PAGE 58, TABLE 21

PLAIN GAGES INSP. ALLOWANCES AND TOLERANCES.

TABLE 2 — GAGES FOR CLASS 1 SCREWS

THDS PER INCH	MAJOR DIA. WEAR ALLOWANCE "GO"	MAJOR DIA. TOLERANCES GO PLAIN RING	GO NOT GO PLAIN RING	GO AND NOT GO COMM. ADJ. SNAP	THDS PER INCH
	1	2	3	4	
80	.0002	.0002	.0002	.0002	80
72	.0003	.0002	.0002	.0002	72
64	.0003	.0002	.0002	.0002	64
56	.0003	.0002	.0002	.0002	56
48	.0004	.0002	.0002	.0002	48
44	.0004	.0002	.0002	.0002	44
40	.0004	.0002	.0002	.0002	40
36	.0004	.0003	.0002	.0002	36
32	.0004	.0003	.0002	.0002	32
28	.0005	.0003	.0002	.0002	28
24	.0005	.0004	.0002	.0002	24
20	.0005	.0005	.0003	.0003	20
18	.0005	.0005	.0003	.0003	18
16	.0006	.0006	.0003	.0003	16
14	.0006	.0008	.0004	.0003	14
13	.0006	.0008	.0004	.0003	13
12	.0006	.0009	.0005	.0004	12
11	.0006	.0010	.0005	.0004	11
10	.0006	.0010	.0006	.0004	10
9	.0006	.0010	.0007	.0005	9
8	.0006	.0010	.0008	.0005	8
7	.0006	.0010	.0009	.0005	7
6	.0006	.0010	.0010	.0005	6
5	.0006	.0010	.0010	.0005	5
4½	.0006	.0010	.0010	.0005	4½
4	.0006	.0010	.0010	.0005	4

TABLE 3 — GAGES FOR CLASS 2 3 & 4 SCREWS

THDS PER INCH	MAJOR DIA. WEAR ALLOWANCE "GO"	MAJOR DIA. TOLERANCES GO PLAIN RING	GO NOT GO PLAIN RING OR SNAP	GO AND NOT GO COMM. ADJ. SNAP	THDS PER INCH
	1	2	3	4	
80	.0001	.0002	.0001	.0001	80
72	.0001	.0002	.0001	.0001	72
64	.0001	.0002	.0001	.0001	64
56	.0002	.0002	.0002	.0002	56
48	.0002	.0002	.0002	.0002	48
44	.0002	.0002	.0002	.0002	44
40	.0002	.0002	.0002	.0002	40
36	.0003	.0002	.0002	.0002	36
32	.0003	.0002	.0002	.0002	32
28	.0004	.0002	.0002	.0002	28
24	.0004	.0002	.0002	.0002	24
20	.0004	.0003	.0002	.0002	20
18	.0005	.0003	.0002	.0002	18
16	.0005	.0004	.0002	.0002	16
14	.0005	.0004	.0002	.0002	14
13	.0005	.0005	.0003	.0003	13
12	.0005	.0005	.0003	.0003	12
11	.0005	.0005	.0003	.0003	11
10	.0006	.0006	.0003	.0003	10
9	.0006	.0008	.0004	.0003	9
8	.0006	.0009	.0005	.0004	8
7	.0006	.0010	.0005	.0004	7
6	.0006	.0010	.0007	.0005	6
5	.0006	.0010	.0008	.0005	5
4½	.0006	.0010	.0010	.0005	4½
4	.0006	.0010	.0010	.0005	4

TABLE 4 — GAGES FOR ALL CLASSES OF NUTS

THDS PER INCH	MINOR DIA. WEAR ALLOWANCE "GO"	MINOR DIA. TOLERANCES GO	NOT GO	THDS PER INCH
	1	2	3	4
80	.0001	.0001	.0001	80
72	.0001	.0002	.0001	72
64	.0001	.0002	.0001	64
56	.0001	.0002	.0001	56
48	.0002	.0002	.0002	48
44	.0002	.0002	.0002	44
40	.0002	.0002	.0002	40
36	.0003	.0002	.0002	36
32	.0003	.0002	.0002	32
28	.0004	.0002	.0002	28
24	.0004	.0002	.0002	24
20	.0004	.0003	.0002	20
18	.0005	.0003	.0002	18
16	.0005	.0003	.0002	16
14	.0005	.0004	.0002	14
13	.0005	.0004	.0002	13
12	.0005	.0005	.0003	12
11	.0005	.0005	.0003	11
10	.0006	.0006	.0003	10
9	.0006	.0006	.0003	9
8	.0006	.0008	.0004	8
7	.0006	.0009	.0005	7
6	.0006	.0010	.0006	6
5	.0006	.0010	.0007	5
4½	.0006	.0010	.0009	4½
4	.0006	.0010	.0010	4

Ordnance Production Gaging

Chapter I—INTERCHANGEABILITY—*Continued*

By RUSH A. BOWMAN

First Lieut., Ord. Dep't, in Charge of Pittsburgh Gage Laboratory

← START ON FACING PAGE

ment. To illustrate, let us take the specifications for the nose thread of a shell—which is an inside thread as in a nut. This thread will be specified as follows:

2 – 12 N S –1

Major Diameter	2.000 minimum
Pitch Diameter	1.9459 + .0106
Minor Diameter	1.9098 + .0090

Four gages will be needed for the inspection of this thread: a "go" and a "not go" thread plug and a "go" and a "not go" plain plug. (In small sizes, of course, these four gages might be two double-end gages. Refer to C.S.8-41 "Gage Blanks.")

To proceed with the design of the "go" thread gage, the smallest major diameter, 2.0000", will be the basic size of the major diameter of the "go" plug. To determine the tolerance, we look under column 13, Table 1, opposite 12 threads per inch, and we find 0.0006. Major diameter of the "go" plug to be obtained and used for inspection should therefore be 2.0000 plus 0.0006.

It will be noted that no wear allowance is made on the major diameter. Pitch diameter of the "go" gage will be basic size, 1.9459, plus pitch diameter allowance (Table 1 column 8 opposite 12 threads per inch) plus pitch diameter tolerance (Table 1 column 10 opposite 12 threads per inch). Minor diameter will be shown as "cleared," which means either a sharp V at the root or an actual cutting away of the root of the thread. Specifications for the "go" gage could then be said to be—

Major Diameter	2.0000 + 0.0006
Pitch Diameter	1.9461 + 0.0004
Minor Diameter	Cleared

To design the "not go" plug, subtract 0.0174 (which is opposite 12 threads per inch, column 12 Table 1) from 2.0000 basic size, and we obtain 1.9826 as basic size of the major diameter of the "not go" gage. Tolerance is the same as for the "go" gage, 0.0006.

From the basic pitch diameter of the "not go" gage, 1.9459 plus 0.0106 or 1.9565, tolerance is negative and 0.0003 as shown in column 11 Table 1 opposite 12 threads per inch. Minor diameter again is merely "cleared." Specifications for the "not go" thread gage may then be said to be—

Major Diameter	1.9826 – 0.0006
Pitch Diameter	1.9565 – 0.0003
Minor Diameter	Cleared

To determine the size of the plain plugs to inspect minor diameter, we refer to Chart I for wear allowance and gage makers' tolerances, plain plug and plain ring inspection ranges. Component tolerance of the minor diameter is 0.0090. We therefore refer on the chart to the line opposite 0.009. We find that the wear allowance is 0.0005 which is added to 1.9098 to make 1.9103. Gage tolerance is plus and as shown is 0.0004. The plain "go" plug for the inspection of the minor diameter of this thread may then be specified 1.9103 plus 0.0004. Minor diameter "not go" would be 1.9098 plus 0.0090 or 1.9188 minus (referring again to the same chart) 0.0002. The plain "not go" plug gage for the inspection of the minor diameter of this thread would then be 1.9188 – 0.0002.

It is not meant that these tables should replace the use of the handbook "Screw Thread Devices for Federal Services," usually known by its 1933 title, "National Screw Thread Commission Handbook." It is an assembling into a short form of the data most commonly used in Ordnance

(Continued on Page 192)

Maintenance and Servicing of Electrical Instruments

By JAMES SPENCER

Foreman, Instrument and Relay Testing, Westinghouse Elec. & Mfg. Co., Newark, N. J.

CHAPTER VI

FREQUENCY METERS

(Continued)

INDUCTION TYPE

Few induction type frequency meters are being manufactured today. There are, however, thousands of these instruments in use throughout the country and, due to their long service, they require more attention now than ever before. In order to keep these instruments functioning properly and extend their useful life, only those familiar with the construction and operation should attempt repairs or recalibration. The following discussion must be carefully studied.

The induction type frequency meter finds application where instantaneous frequency measurements of high accuracy are desired. Its limitations are that varying temperature, self-heating and voltage changes tend to reduce the accuracy of calibration. Amplification of these subjects will be made later in discussing possible causes of error.

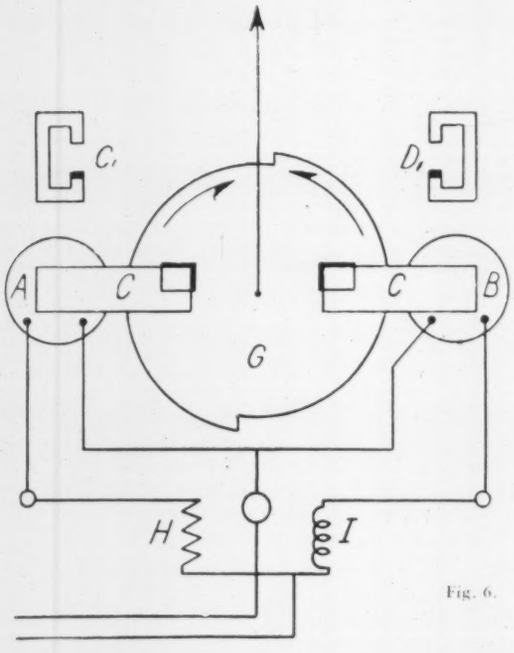


Fig. 6.

This type is made in both switchboard and portable forms. As both are similar in operation and construction (with the exception of the damping magnets included in portables) we shall discuss only the switchboard instruments.

The construction is simple. A cast-iron base with brass terminals and iron mounting studs, and a pressed steel cover with a full-glass front, give the mechanism a good rigid mounting as well as a shielding against external fields. The aluminum disk as shown in Fig. 6, a channel-constructed pointer, and three balance arms to carry the balance weights, are mounted on an aluminum shaft with hard steel pivots at both ends. A cast-iron bracket supports this moving element, which rotates between two sapphire jewels. The felt packing used between the case and cover make the instrument dust-proof.

Principle of Operation

Two coils with C-shaped laminated iron cores (see Fig. 7) constitute the stationary element. The reactor-resistor used with this type consists of two spool resistors and a reactor connected as shown in Fig. 6, and mounted in a case with cast iron base and cover and iron screen sides. Each electromagnet has a copper short-circuiting loop and the portable instruments have two C-shaped magnets.

The instrument is connected across a circuit the same as a voltmeter. The two voltmeter electromagnets, *A* and *B* of Fig. 6, act in opposition on the aluminum disk *G*, tending to rotate it in opposite directions. As shown in the diagram, one coil is connected in series with a non-inductive resistor and the other coil is in series with a reactor of high inductance. The reactance of the *A* coil circuit will change with a change of frequency while the circuit of coil *B* is practically independent of frequency changes. As the disk is not a true circle a change from normal frequency or the point where the two torques balance will not cause continuous rotation. The shape of the disk and its position with respect to the coil is such that the amount of metal in the air gap of magnet *C* is practically always the same, while that under the magnet *C* changes due to the fact that the part of the disk under this side is the arc of a circle whose center is just above the shaft and center of arc of the other side. When the frequency rises, the current through coil *B* becomes smaller and the field weaker than that of coil *A*, causing the disk to rotate to the right of the normal frequency point. A decrease in frequency produces the opposite effect.

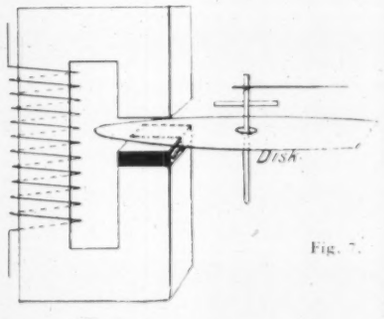


Fig. 7.

As the disk position changes due to a change of frequency, a greater part of the disk is caused to move into the field of the weaker electromagnet. As more metal of the disk moves under the weaker electromagnet, the relative torques of the two electromagnets are balanced and the disk comes to rest.

Tests and Adjustments

A general inspection of this instrument after repairs or as a periodical check would be as follows: A 1500-volt ground test between terminals and metal case is suggested if a test source is available. A check for poor soldering, loose connections, proper end play, true disk properly spaced in air gap, straight pointer and good dial-to-pointer clearance is also advised. Friction may be checked by blowing lightly on the pointer and noting the action of the pointer as it moves across the scale and also if it comes to rest abruptly. Friction can best be checked electrically, however, as slight interruptions in the movement of the pointer are more easily observed under load. In the case of porta-

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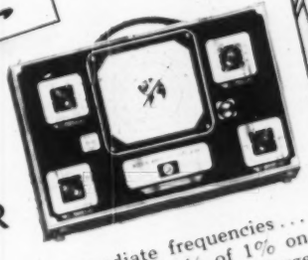

WESTON Model 776 OSCILLATOR

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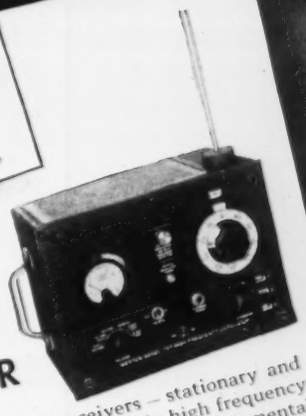
22 mc to 150 mc fundamental frequencies



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IN normal times it is inadvisable for users of electrical instruments (except users such as utilities with full-equipped service laboratories) to do any work which involves opening up the case.

But this national emergency has created a shortage of electrical instruments, so that even plants enjoying priority have to wait. The top shelves of stockrooms are being searched for old instruments. "Irreparable" instruments are being "repaired." And —perhaps most important—all instruments in use must be maintained in good condition . . . by the users. Hence the crying need for this serial—the first and only one of its kind.

ble frequency meters, the disk clearance in the air gap of the damping magnets should be checked.

After the complete inspection as stated above has been completed, the instrument should be connected to the test circuit and allowed to heat for about fifteen to twenty minutes before checking calibration. The purpose is to compensate for the self-heating error in this type of instrument.

The element of an induction type instrument should be so balanced that it will show no tendency to turn when stopped at any point on the scale.

This check should be made with coils de-energized and by moving the pointer by hand to different points on the scale and noting the results. If the element is out of balance, the pointer will move up or down the scale. To rebalance, loosen the small set screw that holds the balance arm hub tightly on the element shaft. The balance arm should then be moved around the shaft until a point is reached where the pointer assumes a position at the center of the scale. The balance arm should then be tightened on the shaft. Next move the pointer first to one end of the scale and then to the other end and adjust the balance weights so that in either position there is no tendency to move up-scale or down-scale.

If, after balance, the instrument is found to be out of calibration, adjustments may be made as follows: The normal frequency point is at the mechanical center of the scale and is adjusted by changing the resistance in the resistor-reactor. The scale ends are adjusted by either adding or removing iron from the reactor, or by opening or closing the reactor air gap in the portable instrument. To lengthen the scale, iron should be added to the reactor; to shorten the scale, iron should be removed. Changing the reactance in this manner causes a change in the normal frequency point which can be corrected by readjusting the resistance in the non-inductive side of the resistor-reactor. To correct the normal frequency point after reactor adjustments have been made, resistance should be removed to advance the pointer position and increased to produce a lower frequency indication.

The instrument cover and iron screen of the reactor should be in place when making calibration checks as they affect readings.

Voltage and self-heating errors in the induction switchboard instrument are reduced to a minimum during initial calibration by carefully adjusting the air gap in the iron of the reactor.

If, during repairs or recalibration in the field, adjustments of the reactor are necessary, care should be exercised in making iron changes so as to allow for an air gap of approximately one-sixteenth of an inch.

These instruments should be calibrated on a circuit of relatively good wave-form, because the accuracy of the induction type frequency meter is affected considerably by distorted wave-form. If the circuit to which the instrument is to be applied has a poor wave-form, the instrument should be finally readjusted *on that circuit* after having been cleaned, inspected and adjusted in the shop.

Sources of Error

The following are a few of the possible cause of errors to be explored if a known frequency is applied to the instrument and the instrument does not indicate that frequency.

Mechanical Troubles

If the moving element does not move freely (that is, if friction is present) the reason will be found by checking as follows:

1. The disk should be carefully checked in all positions to see that it does not touch the electromagnet or other adjacent parts. If friction is due to the disk rubbing, the cause may be the result of a bent shaft, bent disk or the copper "shading" coil on the electromagnet protruding above the face of the laminations.

2. Check the pointer and tail piece for dial clearance and clearance of the bridge respectively. By moving the pointer slowly from one end of scale to the other, the clearance between the pointer and dial can be observed at all points. Lint protruding from the paper dial may also have a tendency to obstruct the free movement of the pointer. The pointer hub clearance with respect to the escutcheon plate should also be checked.

3. Friction due to pivot and jewels may be caused by flat or broken pivots, cracked jewels, incorrect end play, rusted pivots or dirty jewels. To check the pivots for any of the aforementioned defects, it is necessary to remove the elements from the instrument to better observe the pivot under a magnifying glass or microscope. The jewels may be checked for cracks by the use of a fine needle held lightly in the fingers and moved slowly in and around the jewels to detect rough spots. Cleaning of the jewels should be done with an orange stick or some such material that will not scratch the jewel surface.

4. End play of the movement should be held to a few thousandths of an inch. To make this adjustment, loosen the top jewel lock nut and screw the jewel in or out slowly until proper adjustment is had. Hold the element by the pointer and move it back and forth sidewise while making the jewel adjustment, in order to better judge the end clearance and also to prevent jamming the jewel against the pivot (which is a common cause of damage to jewel or pivot). When the end play has been adjusted, hold the jewel screw in position and tighten the lock nut.

Electrical Troubles

Electrical defects that may be caused by accidents, carelessness, etc., are:

open and short circuits,
burn-outs,
no external circuit,
poor connections,
grounds,
partial shorts, and
wrong connections.

The result of an open circuit may be no reading at all, too high a reading or too low a reading, according to which part is open.

If the instrument gives no indication when connected to a live circuit, the trouble is probably due to an open-circuit in the wiring to the common connections of the instrument or resistor-reactor. First, however, make sure that the internal connections are correctly made and that there is a voltage across the input terminals of the instrument and resistor-reactor.

Too high or low a reading indicates that one side of the circuit may be open. An open resistor in the resistor-reactor or an open in coil *A* of Fig. 6 would be indicated by a very low reading. An open in coil *B* or the reactor *I* of the same figure, would result in a very high reading.

Short-circuited resistor, reactor or electromagnet coils result in high and low readings also, according to the extent of the shorted part. If coil *A* of Fig. 6 were shorted completely, a very low reading would result, while a complete

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short in coil *B* would indicated by a very high reading. Both of these conditions would be the effects of a weak field and therefore a weak electromagnet. A short in the resistor *H* would result in a higher voltage across coil *A*, increasing the strength of electromagnet *C*, hence a high reading. Similarly, a low reading would result from a short in reactor *I*.

Partial shorts in any of the electrical elements would give results as explained for complete shorts, but to a lesser degree.

When connecting these instruments, care should be used in following directions and markings as given by the manufacturer. See Fig. 8. If reactor *I* is connected in error to

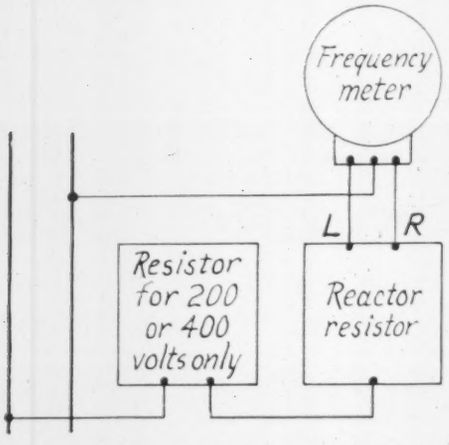

Fig. 8. External connections of induction type frequency meter.

coil *A*, and resistor *H* is connected to coil *B*, any deviation from the 60-cycle or normal point on the scale will give a reverse indication. That is, with a rise in frequency the pointer will indicate lower and with a drop in frequency the pointer will indicate a higher frequency.

Poor connections and intermittent shorts or opens produce *erratic readings*. When this condition is found, check all connections for good electrical contact. Intermittent shorts and open circuits can best be found by checking each

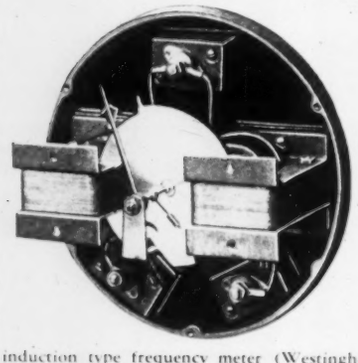

Fig. 9. An induction type frequency meter (Westinghouse "Type SD") with cover, dial and plate removed.

lead, coil or resistor with an ohmmeter, pulling each lead and squeezing the coils to locate the point of trouble.

As stated before but worth repeating, after any work has been performed on an instrument, make a ground test to be sure that energized parts are not in contact with frame or case. The ground test should be made from terminals to base on a circuit of about 1000 volts plus twice the voltage of the instrument. Be sure the ground test circuit is fused or protected to open at a low current (say 0.5 ampere) to guard against serious damage to the instrument if grounded. In addition to the "don'ts" as regards grounds, the "do's" of this subject should also be remembered: when connected to a circuit, the metal case of this instrument should be grounded as a safety measure for both instrument and operator. If the instrument case is not grounded and a ground exist within the instrument, any one touching the case and a ground might be seriously shocked by the existing potential difference between the two points.

Dismantling and reassembling of the induction type instrument can be accomplished by applying the following procedure:

The interior mechanism is rendered accessible by the removal of the three screws holding the cover to the base.

The escutcheon plate and dial may be detached by the removal of the two small screws at either side of the bridge. The metal backing plate for the dial is assembled to the brackets of the electromagnets by four screws with nuts on the under side. Removing them frees the plate from the assembly. This brings the instrument to the view as shown in Fig. 9. The moving element may next be removed by loosening the top jewel and sliding it out.

The electromagnets may be removed by disconnecting the lead wires and removing the screws that hold them to the base.

To insert a new coil, remove the screws holding the laminations together, remove the laminations and the shading coil. Carefully study, or sketch, the construction of the laminations and the position of the shading coil before dismantling, as successful operation depends on the correct reassembly of parts.

When replacing the moving element, follow the instructions for adjusting end-play as previously given.* This adjustment is very important as the pivots may be spoiled by a lack of attention given this important detail.

For the reassembly of other parts, reverse the procedure of dismantling.

ELECTRODYNAMIC TYPES

The electrodynamic principle of operation as embodied in the bridge type and resonant-circuit type frequency meters allows for greater accuracy and sensitivity of operation than is possible by employing any other principle.

The greater refinement of design, to bring about higher sensitivity, has naturally introduced into the field an instrument less sturdy than those of previous designs. While this reduction in sturdiness is not detrimental as regards the useful life of the instrument after it is properly mounted on a modern switchboard, free of vibration, it does present a problem in handling the instrument during transportation, unpacking, installation, and repairing when necessary.

It is not the intention to give the impression that the bridge and resonant-circuit types of frequency meter have been refined to a point where the instruments are too delicate for industrial use, but rather to impress upon the maintenance or repair man the importance of careful handling to extend the useful life of the instrument. In fact, with normal care and handling, the present-day bridge or resonant-circuit frequency meter should maintain its higher accuracy throughout as long a period of service as its more rugged and less accurate predecessors.

BRIDGE TYPE

The dynamometer or bridge type frequency meter is so called by reason of its connections, that is, the instrument (instrument proper and external resistor-reactor) when connected forms a bridge circuit. This type of instrument is usually calibrated with a fairly open scale and is usually held to an accuracy of about one-half of one percent of the indicated frequency—not of the scale range. (This should be borne in mind. Indicating instruments are sometimes condemned for inaccuracies of calibration, when in truth, the fault is due to a lack of understanding on the part of the user in how accuracies are figured.)

The bridge type frequency meter comprises of two moving coils mounted centrally on a shaft at right angles to each other, a divided stationary coil, a two-coil reactor and two resistors. These parts when connected together as shown in Fig. 10 form a bridge circuit, with the stationary coil in series with the bridge.

The steel pivoted shaft, on which the moving coils are mounted, carries also a four-arm crosspiece to which the

*In Chapter I, Fig. 4 and accompanying text. (See *Instruments*, Aug. 1941, page 229.)

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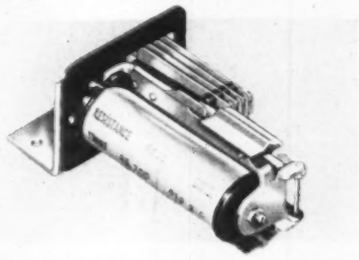

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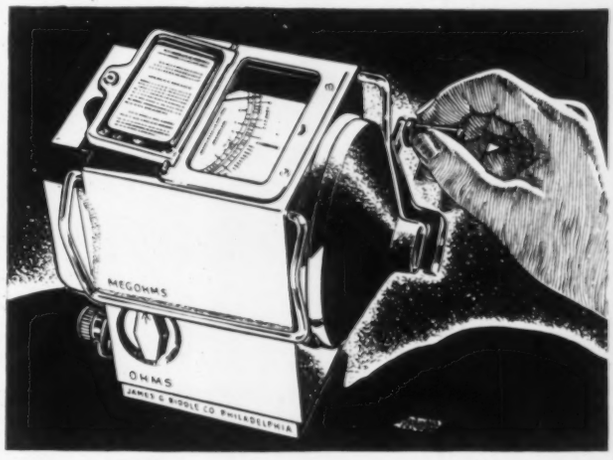

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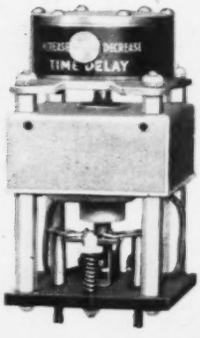

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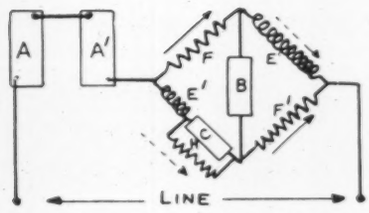

Fig. 10. Simplified diagram of bridge type frequency meter.

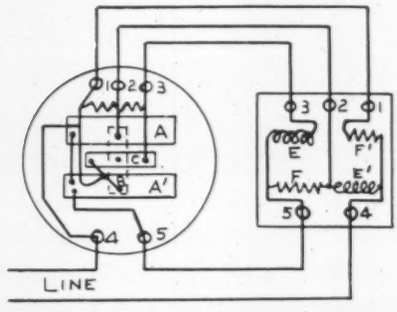

Fig. 11. Internal connections of bridge type frequency meter.

pointer and balance weights are assembled, an aluminum damping vane and three no-torque conducting springs.

The molded sub-base serves as a mounting for the element frame as well as the damping chamber in which the damping vane moves. The lower jewel is assembled in the sub-base while the upper jewel is located in the top bridge that connects the two sides of the element frame.

After the moving element is mounted between the two sapphire jewels, the stationary coils are assembled to the element frame, completing the instrument mechanism. The mechanism is then assembled to the pressed steel base and electrical connections made to the molded covered terminals. The molded terminal blocks and sub-base serve to prevent grounding to the base when connections are made from the external to the internal circuits.

The pressed steel base and cover with its full glass front and its several dust-proof gaskets, constitute a rigid support for the mechanism as well as a shield against external magnetic fields. The two small cover plates of the damping chamber should be held firmly in place by the four mounting screws to obtain the desired damping effect.

The two resistors and two winding reactor are enclosed in a box with iron screen sides and cast-iron bases, to guard against effects of external fields. The external to internal connections of the resistor-reactor are also made through insulated terminals as a safety precaution against accident to either the instrument or the operator.

Fig. 11 shows the internal and external connections of the instrument, as well as the space-positions of the coils at normal frequency.

Principle of Operation

The two resistors, the reactor with two windings, and the stationary coils placed centrally on a shaft at right angles to each other are all connected together in the form of a Wheatstone bridge. The vertical moving coil (B in Fig. 10) is connected across the diagonal of the bridge, while the other moving coil C is connected in series with one winding of the reactor and is shunted with a resistor H.

At normal frequency, which is usually 25 or 60 cycles, no torque is developed and the pointer takes a position at the center of the scale. At this point it is assumed that no current flows in coil B. When the frequency changes, the reactance changes by reason of the $X = 2\pi FL$ relation. As the reactance changes the current in the two circuits E and F changes in value. With an increase in frequency the reactance increases and less current flows through the reactor coil while with a decrease in frequency more current flows. Thus the polarity of moving coil B changes with changes

...ncy from below normal to above normal; and the ... deflects to both sides of the normal frequency point. ...oving coil *C* and the stationary coils *A*-*A'* constitute ...ntrolling device of this instrument. The field of this ...g coil is in space phase with the stationary field at ...l frequency, and in order for the pointer to deflect ... must be enough torque developed to move this moving ...out from the stationary field. The pointer will assume ...sition when the torque force of coil *B* and coils *A*-*A'* ... the retaining action between coils *C* and *A*-*A'* balance. ... damping is obtained by the movement of an aluminum ... in the molded chambers of the sub-base.

Inspection and Tests

The routine or periodic inspection of this type instrument should be of a superficial nature unless the action of the instrument is questionable. This check should consist of changing the frequency slowly to observe the action of the pointer as it moves across the scale. At three or four points on the scale, the pointer should be brought to rest, the pointer position noted and the instrument tapped to ascertain that no pointer movement results due to friction. The cardinal points on the scale should be checked following the procedure outlined below. Slight errors of calibration may probably be due to a change of balance, a condition that can be corrected without removing the instrument from the board. The balance positions and method of balancing are outlined in the detail of test that follows.

All external instrument connections should be securely made and the cover-to-base screws should be tightened to guard against dust or moisture getting into the instrument. The glass of the instrument cover should also be checked for security, as a loose glass means open seams that allow the entrance of dust and moisture.

When a frequency meter fails in its operation, and repairs that require dismantling are necessary, a complete test as given a new instrument is usually required.

Assume that in checking a bridge type frequency meter on a switchboard, it is found that one of the moving coils is defective. This would require the removal of the instrument and the resistor-reactor from the board to make the necessary repairs and recalibration.

On removing the instrument from the board, the usual precautions should be taken, namely, killing the circuit, tagging all leads, insulating all disconnected live leads, etc. The instrument should then be carefully dismounted from the board and taken to a suitable workplace to open and make repairs.

The mechanism of the bridge type frequency meter is rendered accessible by the removal of the cover and dial of the instrument. The brackets that hold the stationary coils to the frame should be removed and the leads from these coils to terminals 4 and 5 (Fig. 11) must be disconnected to allow for dismounting the coils.

The mechanism is now stripped to a point where a detailed inspection of the moving coils is possible. If the coils are found defective and cannot be corrected, a further dismantling is necessary.

To remove the element, the three springs must be unsoldered at the spring adjusters to which the outer convolutions of the springs are attached. The two damping chamber covers may be removed by the removal of the two screws that hold each to the sub-base. The top jewel should next be loosened before removing the bridge that forms the top part of the element frame. The element is now free to be taken out of the frame.

The pointer and top spring are held in place on the shaft by a small hexagon nut that must be removed to disassemble these parts. The small pin through the top of the shaft used to position the pointer, must also be removed before the coils can be taken off the shaft. In order to slide the coils off the shaft the nut holding the coil on the shaft should be unscrewed, and the coil connections to the two lower springs should be unsoldered.

At this point it would be well to examine the pivots at either end of the shaft. As these pivots are pressed into the

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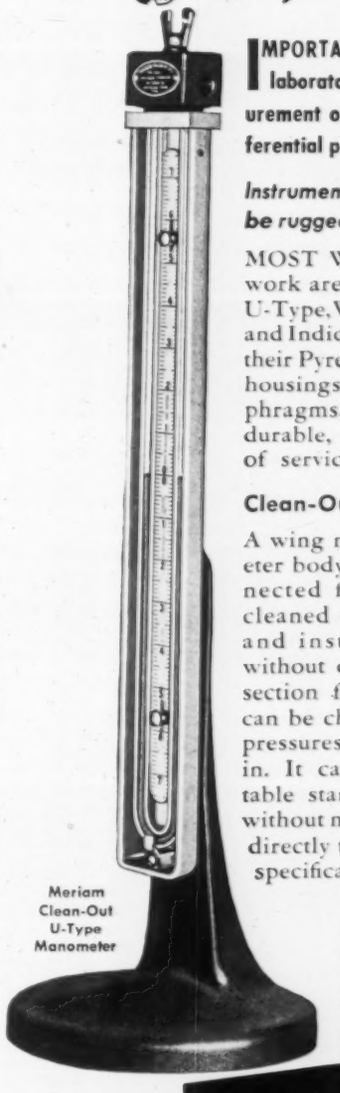

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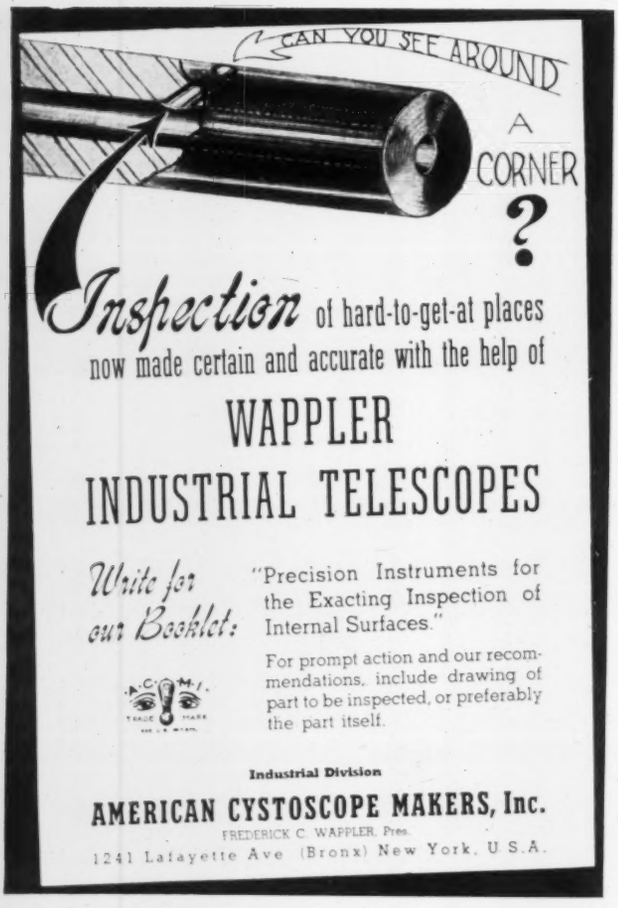

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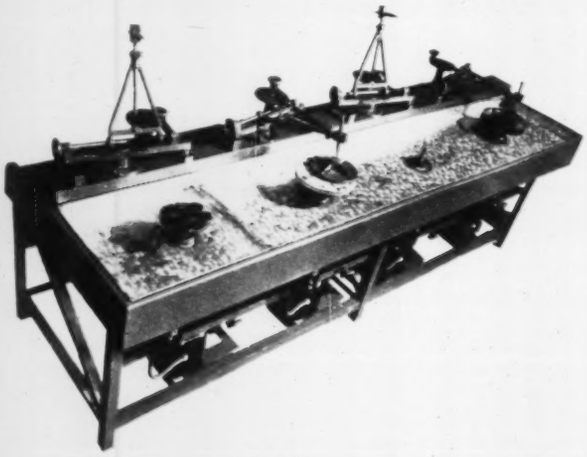

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ends of the shaft, they are readily removable. To remove a pivot, a suggested method is to clamp the pivot in the chuck of a watch lathe or other similar tool and exert a straight outward pull. To reassemble a pivot, it should be held firmly as above and forced into the hollow end of the shaft.

To reassemble the element, mechanism and complete instrument, the reverse of the dismantling procedure should be followed.

Before reassembling the moving coils to the shaft or the stationary coils to the element frame, it is suggested that they be passed quickly through the flame of a lighted match or lamp. This removes the loose ends or fuzz that might be clinging to the coils. Cleaning the pivots and jewels with pith removes dirt, dust and other foreign materials as well as dries up any moisture that might result from touching the pivots with the fingers. Before assembling the damping chamber covers, a close inspection should be made to ascertain that there is sufficient clearance between the aluminum vane and the walls of the damping chambers. Before the stationary coils are assembled, the clear view makes spring inspection an easy operation. While assembling the element shaft in the jewels, the end play should be adjusted as outlined in Chapter I.

When the instrument is completely reassembled, an inspection should be made to ascertain that the instrument is devoid of friction and corroded parts, has good solder connections and tight screw and nut assemblies.

If the instrument has been assembled properly, the pointer will come to rest at the center of the scale when the instrument is placed on the work bench face up. To balance this instrument, the tail weight and two side weights are adjusted until the pointer remains at whatever point on the scale it may be set. To accomplish this, the tail weight should be adjusted so that it just overbalances the pointer weight and allows the pointer to move toward the center of the scale when placed at either scale end. The side weights should then be adjusted to bring the pointer to the mechanical center of the scale, after which a slight adjustment of the tail weight should be made so that the pointer will remain at whatever point it is placed on the scale.

When the instrument has been properly inspected and balanced, it should be given an insulation test to detect any grounded points between the circuit connection of the instrument and the case or between the moving and stationary coils. This test should be for one minute at voltage values of 500 volts between coils and 1500 volts from terminals to case. The ground testing circuit should be fused or have a circuit breaker that will open at a low current (less than 0.5 ampere) to protect the mechanism from serious damage if a ground is present.

If new coils have been installed or if in dismantling the connections were disturbed, a polarity check should be given the instrument for correct pointer deflection. To make this test, connect the instrument as shown in Fig. 12 and apply voltage. If the connections have been correctly made, the

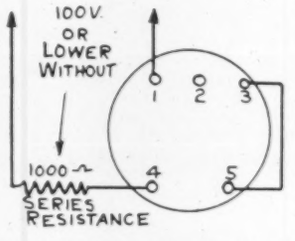

Fig. 12. First connection for polarity test.

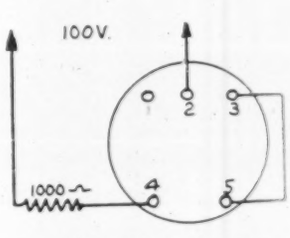

Fig. 13. Second connection

pointer will deflect to the center of the scale. Next connect as in Fig. 13 and apply voltage. With this connection to the line, the pointer should deflect to the extreme left end of the scale, if the internal connections are correctly made.

The instrument is next connected to the test circuit with the reactor-resistor as shown in Fig. 11. With normal frequency on, the pointer should come to rest at the center of

the ... if not, add iron to bring up from left or remove iron ... reactor if pointer is to the right of the center. The ... ends of the instrument are adjusted by changing the ... stance shunt across the horizontal moving coils and equ... the ends by moving the movable coils. If moving coil ... shifted the balance must be reset and the normal fre... cy point readjusted by the iron in the reactor. When the ... bration of the instrument is complete the iron in the rea... is wedged and covered with shellac to assume permanence of calibration. The instrument is next connected to ... variable frequency circuit for marking in the calibration points as outlined in the preceding paragraphs.

RESONANT CIRCUIT TYPE

With improved switchboard construction, doing away with vibration and possible mechanical shock, frequency meter design and construction has tended to be directed toward less ruggedness and greater accuracy. From a greater accuracy viewpoint the resonant-circuit frequency meter has found wide favor. Its wide-open scale allows for greater accuracy and more position regulation of frequency machines where close regulation is a necessity. Frequency meters of the resonant-circuit type may have *a two-cycle scale about five inches long.*

The mechanism of the resonant-circuit type frequency meter is similar in construction to that of the bridge type. An example is shown in Fig. 14. The connections of this cross-coil electrodynamic type mechanism differs from the

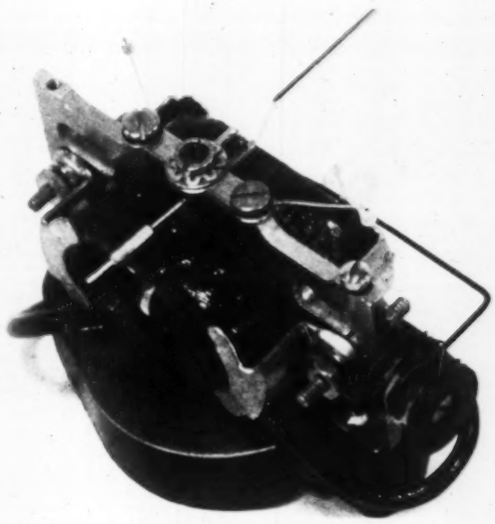

Fig. 14. Electrodynamic instrument mechanism used in both the bridge type and the resonant-circuit type of Westinghouse frequency meter.

bridge type in that one stationary coil lead is connected directly to the common connection of the two moving coils, instead of each having a base terminal for external connections. Included with this type frequency meter is an external capacitor-reactor connected as shown in Fig. 15 to complete the instrument. The internal and external connections of this type are shown in Figs. 16 and 17.

The parts included in the instrument proper as shown in Fig. 14 are almost identical with those of the bridge type as outlined in the preceding section. The external circuit of the resonant type, however, differs from that of the bridge type in that the phase-splitting arrangement consists of a capacitor-reactor instead of a resistor-reactor. A series reactor or harmonic suppressor is a feature of the resonant type not included in the bridge type. Figs. 18 and 19 show the instrument proper and its accessories.

Principle of Operation

Before proceeding with an explanation of the theory on which the resonant type frequency meter operate, it might be well to explain the meaning of the term resonant and the formulas that might enter into this discussion.

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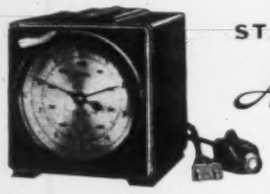

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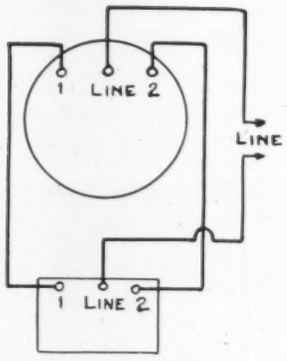

Fig. 15. External connections of resonant-circuit type frequency meter.

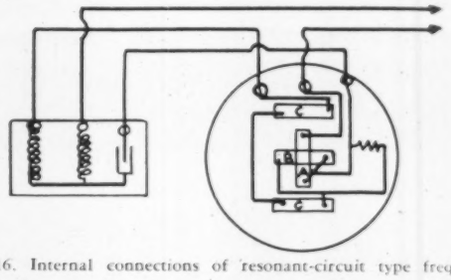

Fig. 16. Internal connections of resonant-circuit type frequency meter.

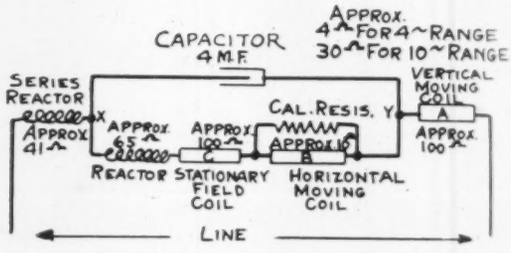

Fig. 17. Simplified diagram of resonant-circuit type frequency meter.

Reactance is the opposition that a circuit offers to the flow of current through the capacitance and inductance in it. It is the factor that when squared and added to the square of the resistance equals the square of the impedance. It is expressed as $X = 2\pi FL$ where F = frequency and L = inductance.

Impedance is the total opposition of a circuit to a varying current, due to ohmic resistance and reactance.

Capacity is the power of containing. A capacitor (commonly called condenser) has unit capacity (farad) when a change of one coulomb creates a difference of potential of one volt across its terminals. As the farad is too large for practical purposes the microfarad is used.

Resonance—A circuit is said to be resonant when the inductive reactance and the capacitive reactance neutralize each other leaving only the ohmic resistance affecting the circuit and producing a current in phase with the impressed voltage.

The resonant type frequency meter makes use of an electrodynamic type movement, consisting of two stationary coils and two moving coils placed at right angles to each other on a pivoted shaft free to move in the field of the stationary coils. When the circuit between X and Y, Fig. 17, is in resonance, the current due to the capacitive reactance and that due to the inductive reactance are equal, leaving only the in-phase component of current to flow in the deflecting coil A of Fig. 17. The current in the restraining coil B, being large as compared to that in the deflecting coil A, tends to hold the pointer at the center position when the circuit is in resonance. With an increase in frequency the current flow through the reactor decreases $[I_x = E/(2\pi FL)]$ and the

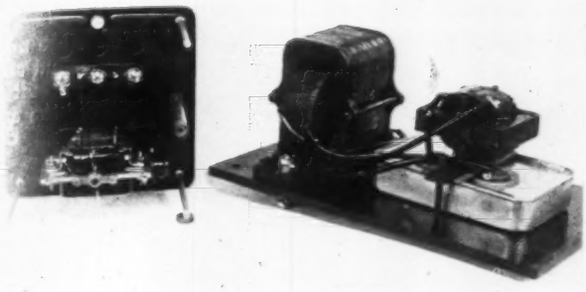

Fig. 18. At left, instrument mechanism; at right, reactor, capacitor and harmonic suppressor, of the Westinghouse "Type HY" resonant-circuit type frequency meter.

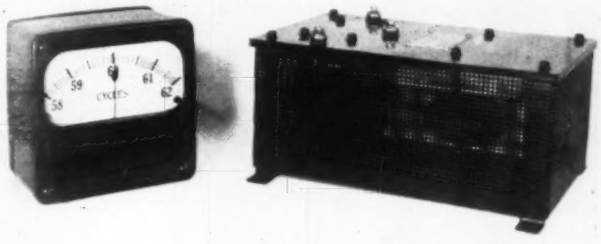

Fig. 19. Same as Fig. 18 but with covers on.

current through the capacitor side increases ($I = E2\pi FC$) causing the pointer to deflect to the right as the current in the deflecting coil increases. With a decrease in frequency the reverse action takes place and the pointer deflects to the left as the polarity of the deflecting coil changes. A series reactor as shown in Fig. 17 is used in the circuit as a harmonic suppressor to reduce wave-form error to a minimum. As the restraining coil moves out of the field of the stationary coils the torque between the two fields becomes greater and will only move to a point where the torques of the two moving coils balance.

Test and Inspection

The inspection of the resonant type frequency meter is, in general, the same as that of the bridge type. A polarity test is given with connections as shown in Figs. 20 and 21. With connections as in Fig. 20, the pointer should assume

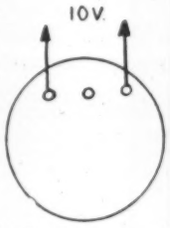

Fig. 20. First connection for polarity test.

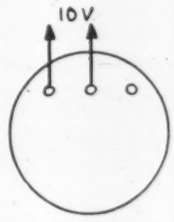

Fig. 21. Second connection for polarity test.

a position at the center of the scale when 10 volts are applied to the terminals. With the same voltage applied and with connections as shown in Fig. 21 the pointer should deflect to the left of the center.

We next connect the instrument and reactor-capacitor as shown in Fig. 16 and adjust the normal frequency point (usually 25 or 60 cycles) at the mechanical center of the scale. This adjustment is made by adding or removing iron from the reactor in the resonant circuit. Although the scale is not uniformily spaced, its distribution is such that readings at any part of the scale may easily be read to limits well within the guaranteed accuracy of the instrument. This desirable scale distribution is however dependent upon the normal frequency position being adjusted as nearly as possible to the mechanical center of the scale. By the proper attention given the position of the normal frequency point, a more desirable distribution of scale may be had.

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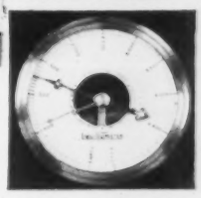

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of the shunt across the moving coil and by shifting the moving coils. After the coils and balance weights are made tight and the reactor laminations firmly wedged and shellacked, the instrument should be connected in circuit at normal frequency for ten minutes before marking the calibration points.

Possible Errors and Corrections

Friction in this type of instrument may result from defective pivots, damping vane rubbing on walls of damping chamber, moving coils rubbing on adjacent parts, lint or fuzz on coils affecting movement of coils, improper adjustment of end play, etc. Due to the relatively low torque-to-weight ratio of the electrodynamic type frequency meter, the mechanical causes as just outlined must be carefully guarded against.

Defective end play adjustment may be corrected as outlined in Chapter I.*

Lint or fuzz on the coils may be found by visual inspection. Probably the best permanent correction of this fault is to remove this troublesome material from the coil by burning it off. One convenient method of applying this corrective measure, is to take a wire paper clip, straighten it out into a long single wire and flatten one end by hammering. This flattened end may be heated and passed over the coils, burning off the trouble-producing material.

Damping vane clearances can best be checked by removing the damping chamber covers and inspecting the clearance with a loupe or magnifying glass. With the damping chamber covers removed, move the pointer up-and down-scale, noting the damping vane clearance over its full length of travel. If the vane is not bent or distorted, the vane clearance may be corrected by adjusting the jewel positions. The damping chamber should be thoroughly cleaned as the vane clearance is so small that even tiny particles of foreign material may cause friction. Loose foreign material in the air gap, usually manifests itself by a changing point of friction (that is, at different points of the scale) with each check.

Although not a common fault, there is always a possibility that distortion of the moving coils may cause the coils to rub on adjacent parts. Shifting the moving coils during calibration may also cause this trouble if care is not exercised in making this adjustment. A visual inspection of the coil clearance should be a sufficient check to ascertain if coil rubbing is present. A loupe or magnifying glass is a helpful piece of equipment for checking coil clearances. When checking for coil clearances, the instrument should be held so that when looking between the coils, the background is either daylight or indirect artificial light.

Remember that the actuating torque in a frequency meter is lower than in most other instruments, so that pivots and jewels must be in perfect condition.

Changes in calibration after a frequency meter is placed in service may be due to many various causes, a few of which are listed below.

Coils shifting. This may be due to a sudden application of a current whose frequency is higher or lower than that of the instrument range. This causes the pointer or damping vane to strike its travel-limiting element sharply. If the coil locknut on the element shaft is tight, and the coil is properly cemented to the shaft, the possibility of coil shifting will be almost entirely eliminated.

Charred coils. If a frequency meter has been accidentally subjected to an overload, an important point of inspection is the condition of the coils. While the overload may not be so severe that it will cause the coil to burn out, it may cause charring of the insulation. Due to this burning of insulation, the weight distribution of the element changes, causing a change in balance and hence a change of calibration.

Balance change. Element unbalance is one of the major causes of calibration errors in frequency meters. Due to the relatively low torque of the frequency meter, as compared

*Page 229 of the August issue of *Instruments*.

most spring-controlled instruments, it is not difficult ason that even slight changes of balance in this type strument will noticeably affect calibration. For this n, it is important to know the possible causes of ele- balance changes. The three points to inspect when nce changes take place are the damping vane, the coils the pointer assembly.

nbalance caused by the damping vane may be due to a rted vane or the vane shifting its position on the shaft se on shaft). Distorted coils, charred coils, coils loose on ft or aging of coils are all items that will cause condi- ns of unbalance in frequency meter moving elements. An inspection of the pointer and cross-arm assembly should include checking the balance weights for tightness, be sure the pointer to cross-arm assembly is not loose, see that the pointer and cross-arms are not bent or distorted and note if the pointer is loose on the element shaft.

Connections. When making connections, be sure to follow all information given by the supplier. Instruments and reactor terminals are usually marked 1, 2, 3, etc. or A, B, C, etc., and should be connected accordingly, that is, A to A and B to B or 1 to 1 and 3 to 3. If the reactor and instrument are connected A's to B's or 1's to 3's, the instrument indications will be reversed, that is, with an increase in frequency, the pointer will deflect down-scale and with a decrease in frequency the pointer will deflect up-scale. Always be sure of good tight connections between the capacitor-reactor and the instrument, as an open or poor connection in the reactor branch of the split circuit will cause a high current to flow in the capacitor circuit and burn out the moving coil (as *A* of Fig. 17) or the conducting springs of this circuit. If repairs are made to a frequency meter, and the polarity of the instrument is reversed, the coils should be rotated 90 degrees on the shaft to correct the fault. Before connecting to a circuit, check data on instrument dial as to voltage, auxiliary equipment used and insulation rating, to be sure of proper application.

Capacitor-Reactor. There should be little if any calibration difficulties due to the capacitor-reactor as there are no moving parts and manufacturers exercise great care in securing all the parts to prevent changes. Accidents such as overloads, etc., may however bring about the need of repairs. The installation of a new capacitor or reactor means that calibration adjustments are necessary. As calibration adjustments are made by adding or removing iron in the reactor, it follows that the baked finish of the reactor is disturbed. This leads to the caution, that the iron should be thoroughly shellacked and dried after adjustment, before final calibration of the scale is made.

Voltage. While most present-day frequency meters are free of voltage errors over normal voltage changes, it should be kept in mind that the lower the voltage, the lower the torque. As the torque is lowered, the effect of inherent friction is amplified, hence calibration inaccuracies. When substantially higher voltages are used, a calibrated series resistor should be used to guard against overloading the instrument.

TUNED-CIRCUIT DIFFERENTIAL-TYPE

Another arrangement of the dynamic and resonant-circuit principle that produces an extremely sensitive frequency meter is that shown in Figs. 22 to 28 inclusive. Here we have two field coils and one divided moving coil connected to a split-circuit arrangement of capacitor-reactors as shown in Fig. 22.

The two field coils *A1-A2* are wound and connected so that the current in each flows in opposite directions. Since the moving coil is in series with the split circuit of the field coils, it will readily be seen that it will carry the sum of the currents in these two coils. The operation of this type of frequency meter is dependent upon the interacting effects of the fluxes resulting from the difference in current in the stationary coils *A1-A2* and the current in coil *B* to which the pointer is attached.

From this it will be seen that since the currents in the

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field coils are in opposition, their fields will be bucking — hence a resultant field equal to the difference in strength of the two fields. The field coil circuits $C1$-$C2$ are so adjusted that the resonant point of each differs by several cycles. That is, if circuit $C1$ were adjusted to resonate at 58 cycles and circuit $C2$ at 62 cycles, then the mean frequency would be 60 cycles—the point where the fields of $A1$-$A2$ balance. As the frequency varies, the moving coil B will move in the direction so that its field will tend to line up with the field of coil $A1$ or $A2$ whichever predominates in strength. If the frequency is below the mid-point, coil $A1$ will have the greater strength and the moving coil will rotate counter clock-wise. For frequencies above the mid-point, the reverse action will take place. The controlling action is supplied by iron vane X shown in Fig. 23, attached to the shaft of the moving element and tending to oppose any change of position of the movement from its mean frequency point. An aluminum vane and a strong permanent magnet as shown in Fig. 26 are employed to produce magnetic damping in this instrument.

The construction of this type of instrument is shown pictorially in Figs. 23 to 28 inclusive, with legends explaining the various parts.

As with all types of electrical instruments, this one should be given a check for mechanical conditions to be sure that all parts have been properly assembled and adjusted. The high points to check are the element balance, the end-to-end movement of the element shaft, clearance of all moving parts, nuts and screws for security, all electrical connections and—last but extremely important—cleanliness of all parts. If new coils or other parts have to be installed, be sure they are identical with those they replace. To be sure of this, always give the manufacturer as much information about the instrument as is possible, so that correct parts may be supplied. All coil and lead insulation should be checked for breaks, to be sure that current-carrying wires are not grounded or shorted.

The planes of the armature coil, vane and pointer should be such that they are within a few degrees of each other. To correct for any misalignment of these parts, loosen them on the shaft, shift to correct position and retighten on shaft.

The inductance coils in the tuned circuit are wound in two parts, a main coil and a tapped auxiliary coil. The taps of the auxiliary coil are brought out at intervals along the coil so that as much of the coil can be used as is necessary when making calibration adjustments. If the inductance of the main coil is too low for calibration requirements, the auxiliary coil is connected in series with it, so that the turns of the two are in the same direction or additive. If

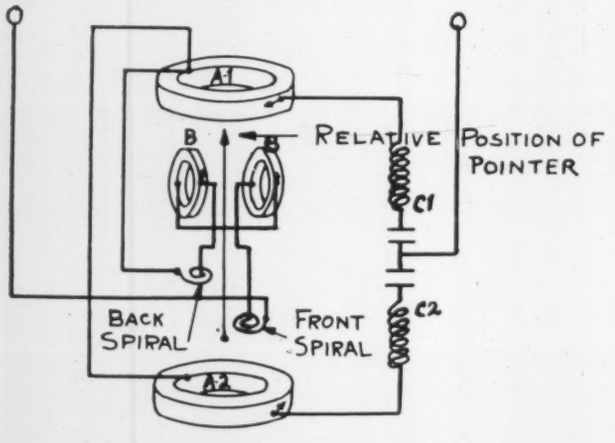

Fig. 22. Schematic view of the General Electric Company's resonant-circuit frequency meter.

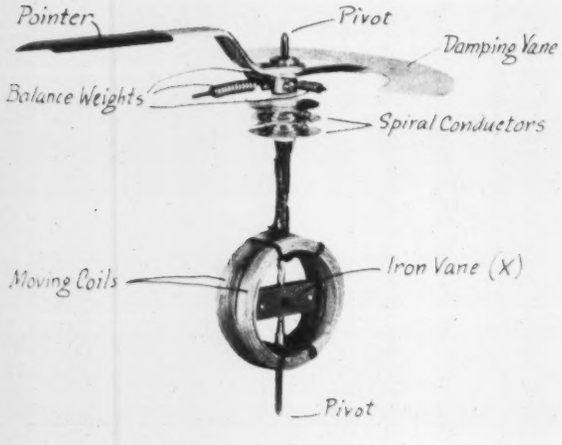

Fig. 23. Moving element of the General Electric resonant-circuit type frequency meter.

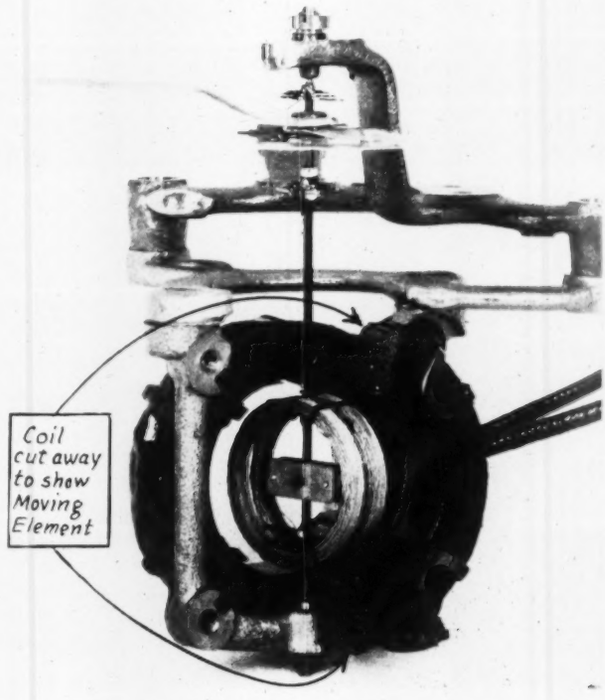

Fig. 24. Mechanism of G-E frequency meter with one coil cut away to show the assembly of the moving element and its position with respect to the field coils.

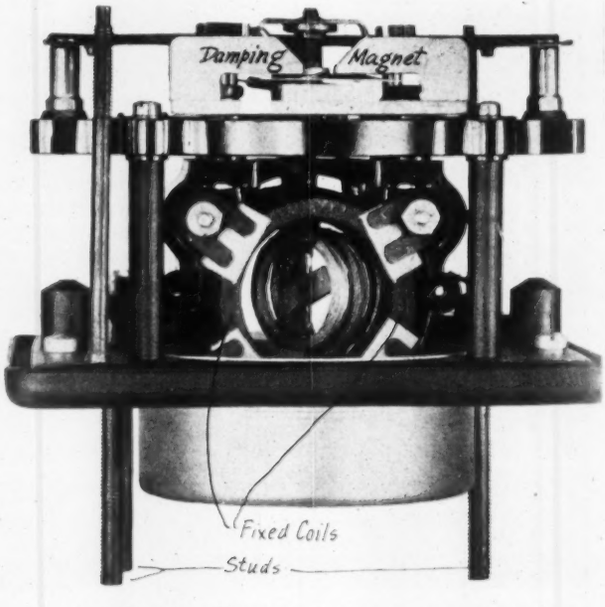

Fig. 25. Mechanism of G-E frequency meter assembled to base, showing internal construction of instrument.

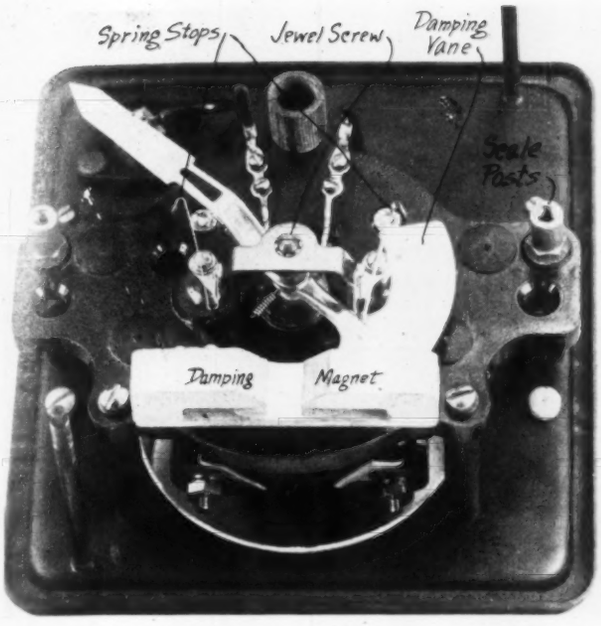

Fig. 26. Top view of G-E instrument with case and dial removed showing pointer, damping vane, damping magnet and connections to element.

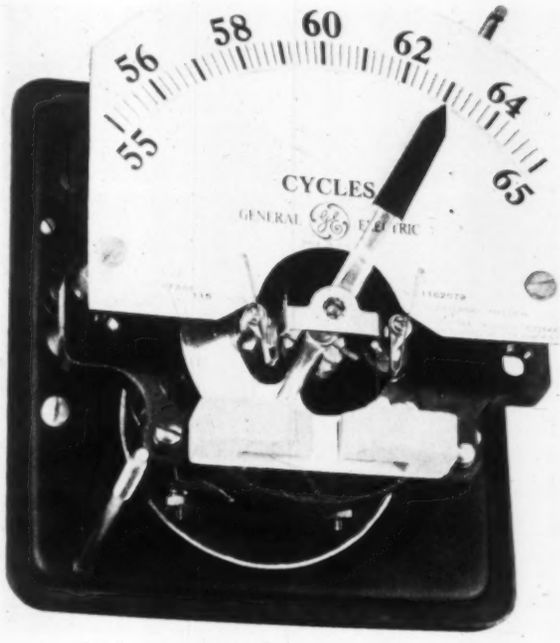

Fig. 27. Complete G-E instrument with cover removed showing anti-parallax dial, pointer, damping magnet and vane, and spring type bumpers.

Fig. 28. Three views of capacitor-reactor as used with General Electric tuned-circuit differential type frequency meter.

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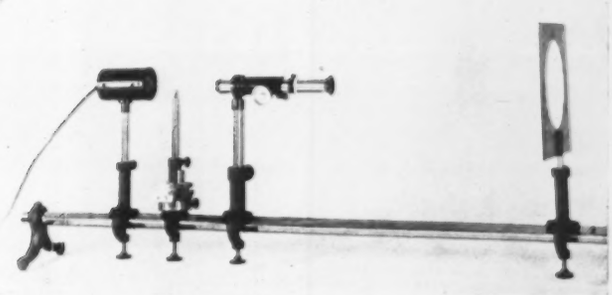

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